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U.S. Beef Industry

Cattle Cycles, Price Spreads, and Packer Concentration

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Abstract

In early 1996, the peak in the current cycle of cattle inventories coincided with a long list of negative factors--negative returns at the farm and feedlot, record-high feed grain prices, a severe drought in 1995-96, widening farm-retail price spreads, a low farmers' share of the consumers' Choice beef dollar, and reports of high profits for beefpackers. This confluence created an atmosphere in which some producers and members of Congress questioned whether the cattle industry was adversely affected by high packer concentration and market power. In this report, we examine the cattle cycle of the 1990's to determine if there are differences from previous cattle cycles and, if so, how and why they are different. We found that values for many variables at the 1996 cyclical peak in cattle inventories, while bad, were not the worst on record. Further, price levels during the cattle cycle of the 1990's were better, our models suggest, than they could have been, given earlier patterns of price adjustment. Finally, despite the growth of packer concentration, we failed to demonstrate large negative effects of packer concentration on cattle prices during the 1991-to-present cattle cycle.

Keywords: Cattle cycles, price spreads, packer concentration, cattle slaughter, steer and heifer slaughter, and cow slaughter.

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Summary

Is the cattle cycle that began in 1991 worse than previous cycles? This is the question that some financially stressed cattle producers asked when they called on the Federal Government to intervene in cattle markets. This report, a study of relationships among cattle cycles, price spreads, and market concentration, concludes that the 1970's cattle cycle was worse for ranchers than the current cycle, and that farm prices in the current cycle may actually be better than one might expect.

Cattle producers generally accept cattle cycles. However, in 1996, a combination of events created an atmosphere in which some producers charged that the cattle industry was adversely affected by high concentration and market power of beef-packing firms. These events included low cattle prices and widening farm-to-retail beef price spreads, a low farmers' share of the consumer spending on Choice beef, negative returns to cattle producers, and reports of high profits for beefpackers. In addition to these perceptions, peak cattle inventory numbers for the cattle cycle of the 1990's coincided with record-high feed grain prices. The U.S. farm price of corn, which averaged $2.26 per bushel in 1994/95, rose to a peak of over $5.00 in July 1996. Further, the severe drought in 1995 and 1996 in some major cattle-raising areas forced many producers to reduce cow herds as forage supplies declined. Allegations were made that packers were using their market power to lower bids for cattle, thus lowering prices that producers received.

Several test results indicated that the link between the cattle cycle and increasing concentration in the beefpacking sector runs counter to these perceptions. The study results indicate that the cycle of the 1970's was worse than the cycle of the 1990's, with average estimated losses for cow/calf producers almost twice as bad per cow at the low point in the 1970's as in 1996. Further, while overall price spreads for Choice, yield grade 3 steers are growing wider over time, the farm-to-wholesale portion is only slightly wider than its narrowest levels since at least the 1970's in nominal dollars. In real dollars, the spread is at its narrowest levels since before the 1970's. Test results showed no evidence to support the assertion that increasing slaughter concentration results in lower farm prices. The wholesale-to-retail portion of the price spread is growing because of costs for additional packing services and new products in the packing industry.

The U.S. Beef Industry
Cattle Cycles, Price Spreads, and Packer Concentration

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Introduction

Cattle producers generally acknowledge the existence and importance of the cyclical behavior of cattle inventories, which have peaked in the United States about once a decade for the last century. Many cattle producers say, however, that conditions during the cycle that began in 1991 are worse than conditions during previous cycles. In 1996, a combination of conditions created an atmosphere in which some producers charged that the cattle industry was adversely affected by high concentration and market power of beefpackers (U.S. Department of Agriculture, 1996). These conditions included: (1) low cattle prices combined with widening farm-to-retail beef price spreads, (2) a low farmer share of consumer spending on Choice beef, (3) negative returns in the feeder and fed cattle markets, and (4) reports of high profits for beefpackers. In addition to these perceptions, peak cattle inventory numbers for the cattle cycle of the 1990's coincided with record-high grain prices. The U.S. farm price of corn, which averaged $2.26 per bushel in 1994/95, rose to a peak of over $5.00 in July 1996. In addition, severe drought in 1995 and 1996 in some major cattle-raising areas forced many cow-calf producers to reduce cow herds as forage supplies declined. Packers were accused of using their market power to lower bids for cattle, thus lowering prices for producers. Some financially stressed livestock producers pressed for government intervention in cattle markets.

This report presents results of a set of related analyses designed to bring perspective to the allegations and the debate surrounding cattle cycles, price spreads, market concentration, and the interactions of the three. One objective of this study is to test the hypothesis that conditions at the turning point in this cattle cycle of the 1990's were no more severe than those of past cattle cycles in terms of inventory, price, price spread, or net income effects. Results from tests of this hypothesis indicate that the cycle of the 1970's was actually much worse than this cycle of the 1990's, with average estimated losses almost twice as much per cow at the low point in the 1970's as in 1996 for cow/calf producers. Further, while overall price spreads for Choice, yield grade 3 steers are growing wider over time, the farm-to-wholesale portion is only slightly wider than its narrowest levels since at least the 1970's in nominal dollars. In real dollars, the spread is at its narrowest levels since before the 1970's. We found no evidence to support the assertion that increasing slaughter concentration results in lower farm prices. The wholesale-to-retail portion of the price spread is growing because of packing-industry costs of added packing services and new products.

We begin this report with a background section where we describe and characterize cattle cycles and price spreads. We also present a historical sketch of increasing packer concentration and provide statistical analysis of the current cattle cycle. Accompanying economic data are examined to see if there are statistically significant differences from previous cattle cycles. We find that the most recent cycle's turning point is within the bounds associated with

previous cycle turning points, especially with respect to cow/calf profitability measures. Other cycles offer examples of more extreme values for selected variables like rates of change in cattle inventories, net returns per cow, and duration of various phases of the cattle cycle.

The next section of the report returns to price spreads and focuses on the relationships between price spreads and both the cattle cycle and packer concentration. The section begins with some general observations on the long-term and short-term behavior of price spreads. The model, more fully described in Appendix B, is an asymmetric model of three equations to characterize net farm, wholesale, and retail Choice beef price movements. We modified the model in several ways to examine interactions between prices at different levels in the farm-to-retail chain, as well as effects of the cattle cycle and packer concentration on price spreads. The asymmetric character of our model comes from a specification incorporating supply and demand variables that allow differences in the magnitude and speed at which prices adjust either up or down. Economists have estimated many models where the farm price moves first and drives the wholesale price, which in turn drives the retail price. Rather than pick the farm level (or any other) as the primary driver of all prices, our asymmetric model allows the retail, wholesale, or farm price to drive the others, and allows for complex interactions where all prices adjust simultaneously to movements of the others. Combining the price spread work with cattle cycle phenomena, we find only small cattle cycle-related effects on price spreads. We also find that, rather than being too low or wide, prices may not have been as low and price spreads may not have been as wide as model results indicate they could have been.

The last section of this report describes results from previous studies and the measures we developed and used to measure packer concentration. Then, we assessed these measures through the 1991-to-present cattle cycle. These measures did not indicate that increased packer concentration adversely affected cattle markets. This section includes the results from modifying our asymmetric model to test for packer concentration effects on price spreads. We end the report with a brief section containing our conclusions and some possible implications.

Characteristics of Cattle Cycles

Many agricultural commodities exhibit cycles, that is, some quantifiable characteristic, like size, prices, or numbers, that increases to high levels, reaches a peak, declines to a low level, and then repeats the fluctuating pattern. In nature, cycles occur because the biological lags encounter biological constraints, such as maximum carrying capacity of a species' habitat, an increase in a predator species, or other limiting natural phenomena. When the environment is constant, these life cycles are relatively uniform and vary, depending on the time it takes for individuals within each species to reach each stage in its life cycle. When taken over whole populations, these life cycles generate longer population cycles that we recognize by various names, like the cattle cycle. When the environment is not constant due to drought, disease, or other phenomena, large variations in the regularity of these cycles can occur.

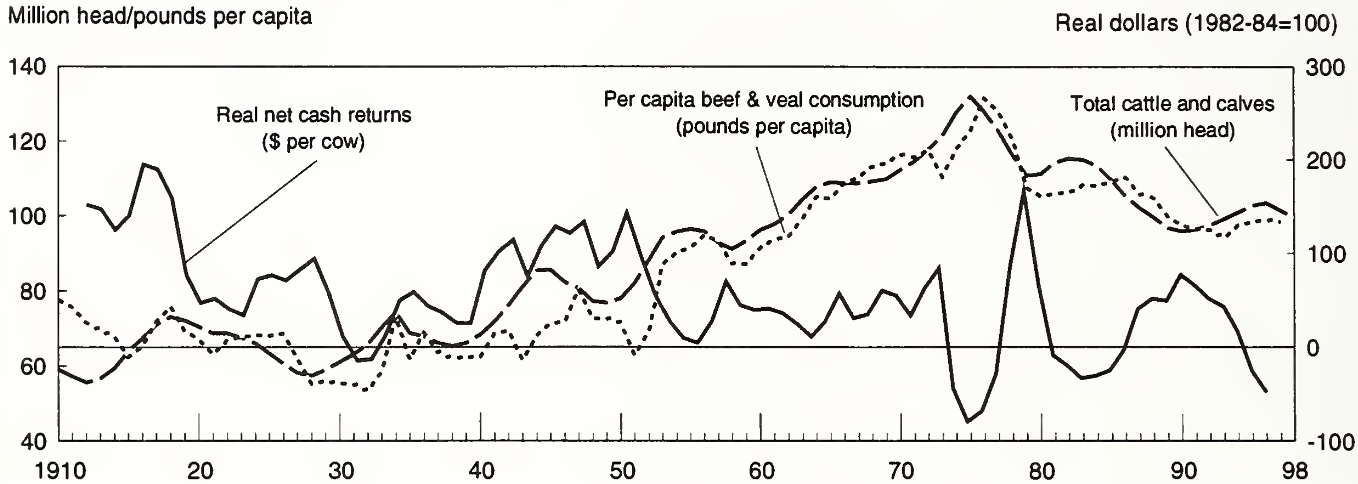
In agricultural commodities, economic phenomena often provide the limits to commodity population inventories. Cycles in supplies and prices of agricultural commodities occur because of the aggregate effects of interactions between the limits imposed by nature and the economic environment and biological lags in life histories of agricultural commodities. At least in this century, and likely for much longer, cycles in agricultural prices and profits have occurred while cyclical supplies faced a relatively constant or slowly changing demand.

The environment in which the cattle cycle operates includes variations in economic activities in addition to the natural and biological factors that influence the length of cattle cycles. Earlier studies attributed cyclical behavior in cattle numbers to weather, grain exports, government programs, and other factors in addition to biological lags (Rucker, Burt, and LaFrance, 1984; Crom, 1981; and Arzac and Wilkinson, 1979). Cyclical fluctuations in U.S. cattle numbers have been observed since at least 1867.

The cattle cycle lasts about 10 to 12 years (Mundlak and Huang, 1996, p. 858; Trapp, 1986, p. 699; Crom, 1981, p. 1; and Franzmann and Walker, 1972, p. 507). It consists of about 6 to 7 years of expanding cattle numbers, usually followed by 1 to 2 years in which cattle numbers are consolidated, then 3 to 4 years of declining numbers before the next expansion begins (Crom,1981, p. 1). However, economic factors or natural factors can shorten or lengthen the whole cycle or any of its phases (fig. 1). Cattle inventory numbers began to climb just after the Civil War and continued to climb for about 23 years before reaching a peak in 1890. Cattle numbers then declined until 1895, when the next expansion began. The expansion that began in 1896 peaked in 1904, a period of 8 years, then declined until 1912, a cycle of 16 years from inventory low to low. The cycle of the 1980's lasted 10 years from low to low, but the expansion phase lasted only 3 years. The periods of time between cyclical peaks or lows in cattle numbers have shortened over time.

Cattle prices also fluctuate during cattle cycles, but have their own patterns, somewhat but not perfectly correlated with cattle inventories. Mundlak and Huang (1996) observed that, while cow stocks and slaughter showed distinct 10-year cycles, prices showed a different pattern. One peak for slaughter prices appeared at 11 years and another much more apparent peak at 22 years (their fig. 1, p. 859). These peaks coincided with cattle cycles in the 1950's and 1970's, two of the more extreme cattle cycles of recent decades.

Figure 1
Total U.S. cattle and calves, real net returns per cow, and per capita beef and veal consumption, 1910-98



Note: Costs exclude capital replacement.
Source: USDA, ERS.

Cattle Inventory Adjustments

Crom (1981) listed seven factors that can influence the severity of biological and economic effects on a cattle cycle: weather, feed grain exports, feed prices, consumer income and expenditures, inflation, changing consumer preference, and the structure of cattle feeding. Inflation had a tremendous effect on many aspects of the economy, including the cattle sector in the late 1970's and early 1980's. These factors combined in the 1970's in a way that made that cyclical downturn one of the most extreme since the 1950's (Crom, 1981). Some authors attribute the shortened expansion phase of the 1980's cycle to sharply decreased demand for beef (Purcell, 1996), while others give more weight to various supply-side events, including drought, conversion of pasture to cropland, and the effects of high interest rates on production costs. These same factors, or closely related variations, appear to have deepened the downturn of the 1990's cattle cycle.

Weather Effects

Weather's main effects are on pasture, forage production, and crop production (Rucker, Burt, and LaFrance, 1984; Crom, 1981; and Arzac and Wilkinson, 1979). The more widespread the weather effects, the more widespread and severe the cyclical responses. If snow or rainfall is below average in many areas, available pasture is reduced during the grazing season, which is generally May through September in the midplains, a longer season farther south, and a shorter season farther north in the United States. Drought can begin to reduce available pasture anytime during the grazing season, and when that happens, cattle producers have two options: They can sell cattle to bring their grazing requirements into line with their available pasture and forage resources, or they can feed supplemental harvested forages. Either of these alternatives has further negative shortrun effects on the beef cattle operation. Rucker, Burt, and LaFrance (1984, p. 139) observed that hay production was better than hay prices as an explanatory variable in their dynamic model of cattle inventories, primarily as a measure of winter feed availability, but also as a measure of the quality of pasture and range conditions--as affected by weather--and a measure of the intermediate-term commitment of resources to cattle production. It is interesting that Rucker, Burt, and LaFrance failed to get significant responses from prices of other feedstuffs (p. 141). Other studies have found significant, though not always large, effects from grain and feedstuff prices (Arzac and Wilkinson, 1979, pp. 299-302).

If operators choose to remove cattle from pastures, they disrupt their normal timing of cattle sales or cash flow, selling younger cattle at lighter weights. These premature cattle sales combined with planned sales mean more cattle going to market than normal. With demand fixed or slowly changing, increased sales volumes exert downward pressure on prices, which, combined with reduced weights per head sold prematurely, translates into lower receipts for cattle producers. At this point in a cattle cycle, one often observes a narrowing of the differential between lighter calves and yearlings and heavier calves and yearlings.

The normal price relationship between lighter calves and yearlings and heavier calves and yearlings is for lighter, younger calves to sell at higher prices per hundredweight (cwt) than heavier, older calves. This happens because lighter, younger cattle generally gain more on a given amount of feed than heavier, older cattle. When feed is relatively cheap compared with cattle prices, producers can make more money by buying lighter calves and feeding them longer. When feed is relatively expensive, producers make more money by buying heavier cattle that will not require as long a feeding period. On occasion, the differential has been reversed and the lighter cattle actually sold at a lower price per cwt than the heavier calves and yearlings.

Drought effects are often manifest in late spring or early summer, as in 1996, but can happen at other times, depending on pasture and range conditions. For instance, during a winter drought, wheat pasture in the southern Plains may be affected, causing cattle to move to feedlots during the winter or even late fall at lighter weights than otherwise. If operators choose to feed supplemental forages or other feeds, their operating costs increase. The increase comes from increased quantities of feed fed to livestock and often concomitant higher prices for hay, other forage, grain, and other feedstuffs from increased demand and drought-induced lower supplies.

Grain and Beef Trade Effects

Grain exports and livestock exports and imports are increasingly important factors affecting cyclical variations in cattle numbers and prices. During cyclical peaks in cattle inventories, even ordinary numbers of cattle imports can appear extremely burdensome. Arzac and Wilkinson (1979, pp. 304-305) observed transitory and permanent effects of corn exports on beef and cattle prices. Beef imports have also been demonstrated to have an inverse relationship with domestic cattle prices. Mundlak and Huang (1996) concluded that "relative sizes between “price peak” and “supply peak” agree with how foreign-trade-oriented [a] country's beef industry is" (p. 868). However, as one might expect, given the manufacturing quality of beef normally imported, only minor effects are reported for fed beef and high-quality cattle, most of the effects being on nonfed beef and cow prices (Freebairn and Rausser, 1975, pp. 685-686).

Cropping and Commodity Program Effects

In addition to effects of the international grain trade, U.S. commodity program policies affect the cattle cycle by motivating substitutions between cropland use as cropland or as improved pasture. Further, Bobst and Davis (1987) suggest and provide evidence that cattle numbers fluctuate in an inverse relationship to changes in the number of harvested crop acres--a finding consistent with Rucker, Burt, and LaFrance (1984). Bobst and Davis estimate that beef cow numbers would decline by 36,600 head for every 1-million-acre increase in productivity-adjusted harvested cropland. They attribute "the explanation of why beef cow inventories broke away from their usual cyclical pattern in the 1980's" to substitution of cropland for pasture and rangeland and the rapid expansion of cropland during this period (p. 774).

Beef Industry Structure Effects

Changes in the characteristics and technologies of not only cattle feeding, but in cattle production and cattle slaughter as well, have had an effect on more recent cycles. For instance, increased average cattle weights have coincided with the building of new slaughter plants able to handle larger carcasses (or vice versa). This is especially noticeable since the 1970's, which were characterized by relatively stable slaughter weights because older packing plants were somewhat constrained in the size of carcasses they could process. In the early 1980's, an influx of new and updated packing plants stimulated a rather large increase in average cattle weights. Increased weights have caused the last two cattle inventory cycles to fluctuate around what appears to be a slight downward trend. This is a reversal of the uptrend of pre-1970’s cycles, even though beef production has generally trended upward for several decades.

Demand Effects

Finally, consumer income and expenditures and consumer preferences for competing meats, or for no meats at all, are demand factors having increased effects on beef's market share of the consumers' meat expenditures and cattle cycles. Per-capita beef consumption (pounds of carcass beef per person) increased slightly after World War II, and has been relatively constant for most of the last 40 years. However, the large cyclical buildup in cattle inventories during the 1970's caused a temporary upward jump in per-capita beef consumption measures. So, looking at data for the last 25 or 30 years leaves one with the impression that per-capita consumption is declining. In addition, since 1986, more fat is trimmed off primal cuts of beef than before, shifting quantity measures slightly lower and contributing to the impression that beef consumption is declining. Even though per-capita beef consumption has remained relatively constant, beef's market share has declined since before the 1970's as per-capita poultry consumption has increased.

Price Spreads

Farm-to-wholesale and wholesale-to-retail beef price spreads often become an issue when producer prices are low or falling and retail food prices are high or rapidly rising. Several congressional hearings, task forces, and commissions have addressed price spreads since the 1970's, alternately concerned with low or falling producer prices or high or rising consumer prices.

Price spreads for beef have been computed since the early 1920's, when Congress asked the U.S. Department of Agriculture (USDA) to undertake special studies of marketing margins for livestock. In 1934, at the request of livestock producers, USDA developed a statistical series to measure changes in marketing costs for a number of agricultural commodities. A preliminary report was published in 1935 and a report was issued in 1936 on price spreads for 58 food items, including beef. Price spreads for beef have been published on a regular basis since 1942, initially in *Marketing and Transportation Situation* and since 1975 in *Agricultural Outlook* and in various *Situation and Outlook* reports published by USDA's Economic Research Service (ERS).

The Retail Choice Beef price series used in price spreads is a weighted average of prices of Choice beef cuts and hamburger published by the Bureau of Labor Statistics (BLS). The weights chosen approximate the quantity of each type of cut that can be taken from a Choice beef carcass. This weighting is designed to maintain a constant quantity and quality of product at the farm, wholesale, and retail levels. Although the beef from a Choice carcass is assumed to be sold somewhere, whether in restaurants, grocery stores, or export markets, only meat sold in grocery stores is represented in the price spread series.

There are several ways to weight different cuts to arrive at a value for the beef from one carcass, depending on the specific nomenclature of the individual cuts. Some experimental work in ERS using principal component analysis has shown that over 95 percent of the variation in BLS cut data is captured in the first principal component (Hahn, internal analysis, 1996).[1] This indicates that reweighting cuts would result in a slightly different weighted average carcass price, but the resulting price series would likely be highly correlated with the current series. In econometric work, either series would give similar results.

ERS also publishes an All Fresh Beef price series, which includes prices for non-Choice cuts and additional hamburger from cows and imported sources. This price also incorporates how much of each type of beef is produced, but not how much of each type is sold from retail counters. No data are available on a frequent and timely basis that would reveal the distribution of cuts actually sold. Because it includes lower quality beef, the fresh beef price is lower than the Choice Beef Retail price. However, the Choice price, the All Fresh beef price, and BLS's Beef and Veal Price Index are all highly correlated (fig. 2).

[1]Principal component analysis is a statistical technique that separates linear combinations of factors into groups that may be considered as variables or proxies for variables in further analyses.

Price and Price Spread Data Issues

Price and price spread data must be interpreted with care. Misinterpretation of these data and indicators can lead to unwarranted conclusions about prices and price spreads. Here, we discuss three issues especially relevant to this report: (1) the interpretation of price spread data, (2) the methods used in calculating the Choice Beef Retail Price, and (3) the fact that special or sale prices are given no more weight than standard prices by the Bureau of Labor Statistics (BLS).

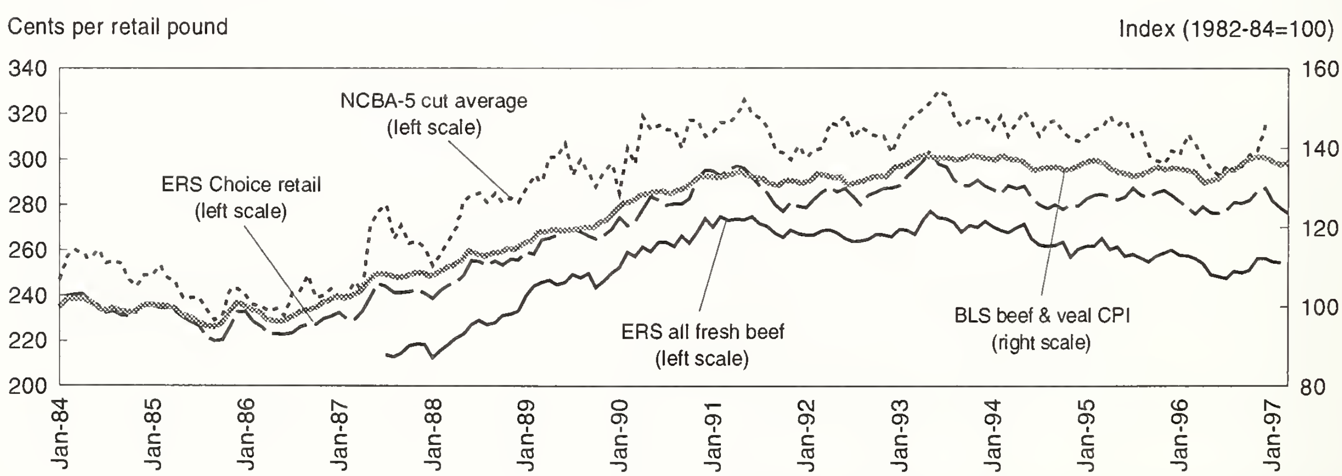
Interpreting price spread data. Changes in price spread data include changes in cost efficiency for slaughtering and processing Choice beef. Over time, the Choice beef price spread measures all the costs and changes in those costs (and profit or losses) of converting a live animal and transporting Choice beef to the grocery store. Even so, it does not provide any direct indication of whether observed price changes are cost-justified. Neither does it separately measure costs or profits for any one type of firm or industry group.

Calculating the Choice Beef Retail Price. Some observers, especially retailers, have criticized the retail price used in price spreads because they feel it does not reflect the distribution of beef cuts actually sold out of meat cases in grocery stores. First, the Choice Beef Retail Price reflects only the price of Choice beef, while many stores also sell other grades of beef. Many critics also feel that, even within the Choice beef grade, fewer steaks and roasts are sold in retail foodstores and more lower value hamburger is sold than is reflected in the Choice Beef Retail price.

Weighting of beef retail prices. Special or sale prices are given no more weight than standard prices in calculating the Choice Beef Retail Price (Tomek, 1996; and Duewer, 1969). BLS collects whatever price is in effect, regular or special, at the time data are collected. BLS has no data to support and makes no adjustment for possible increased volume of sale-priced items. No indication is given in the published BLS data series for frequency or incidence of special prices. This BLS methodology is used for all retail price series collected by BLS and is not unique to meats.

Some critics argue that a retail price more directly reflective of special prices would not only be lower than the ERS price but would more closely track farm and wholesale prices. Unfortunately, no data are available to test that hypothesis.

Figure 2
Retail beef price measures, January 1984-April 1997



Note: CPI is Consumer Price Index, NCBA is National Cattlemens Beef Association, and BLS is Bureau of Labor Statistics.
Source: USDA, ERS.

Beefpacker Concentration

Market power in the meatpacking industry has been a concern among livestock producers since at least the 1890's.[2] In the early 1900's, the packing industry was dominated (perhaps 50 to 75 percent, depending on market definition) by five firms: Armour, Cudahy, Morris, Swift, and Wilson (the Big Five). Several species of livestock were typically slaughtered within a multistory plant, which was generally located at or near a terminal livestock market. Packer branch houses in population centers provided a local sales outlet to then small retailers.

The Packer Consent Decree of 1920 resulted from a Federal Trade Commission investigation of alleged anti-competitive practices on the part of the Big Five meatpackers. Allegations included the use of collusive devices such as market pooling. The packers entered into a consent decree wherein they agreed: (1) to divest themselves of public stockyards, stockyard railroads, market newspapers, and cold storage facilities, (2) not to engage in retailing of meat and other commodities, and (3) to submit to perpetual jurisdiction of the U.S. District Court. Because of mergers, reorganizations, and later court actions, the decree is without practical effect today. But it does provide the background for producers' suspicion of packers and for their expectations of government involvement.

Following the decree, the proportion of slaughter accounted for by the largest four firms declined (Morris merged with Armour), perhaps partly because of the consent decree, but also because of improved transportation, roads, and communication; increased use of Federal grades for beef; movement of livestock production farther west; and growth of retail chains. Following World War II, these forces accelerated. New independent single-species, single-story slaughter plants were built near production areas and away from terminal markets. Along with a decline in the top four firms' portion of total cattle slaughtered by all firms (the four-firm concentration ratio or CR-4 (Connor, Rogers, Marion, and Mueller, 1985, p. 70)), the market shares of the largest four firms rapidly declined, to 30 percent by 1956.

In the 1960's, the boxed beef revolution began. Pork packers had for decades cut hog carcasses into smaller cuts for further processing into bacon, ham, and sausage. Although not the inventor, Iowa Beef (later IBP) was a pioneering firm in effectively making the change to further processing (cutting beef carcasses into primal or subprimal cuts, packing cuts in plastic wrap, and shipping boxes of individual cuts). This process fostered incorporating assembly line processes into meat cutting, reduced shipping weight, improved handling ease and shelf life, and offered a broader range of alternatives to purchasers. Other packers quickly followed, especially the independents.

In the early 1970's, cattle slaughter increased to record levels, accommodating expansion by the aggressive independents, and the CR-4 remained below 30 for steer and heifer slaughter. But, in the late 1970's, after the dramatic downward shift in the previous general uptrend in cattle inventories, the number of cattle slaughtered dropped dramatically, returning to levels more in line with the general up-trend in total beef production and precipitating a shake-out among beefpackers. Hog slaughter continued to increase and the old line packers gave up much of their beef slaughter share to the new breed of packers and concentrated on pork slaughter. By 1980, IBP, MBPXL (formerly Missouri Beef and later Excel), Dubuque, and Land o'Lakes were the four largest steer and heifer slaughterers, supplanting the original Big Four, and the CR-4 for steer and heifer slaughter was about 36 percent.

As the industry evolved, steer and heifer slaughter and cow and bull slaughter were largely separate in plants and firms, partly because culled beef and dairy cows continued to be sold in relatively small lots and remained more geographically dispersed. As feed grain production increased in the Great Plains with the development of irrigation, steer and heifer marketings became concentrated among very large feedlots in four or five States after the 1960's.

[2]Meatpacking includes all aspects of slaughter, fabrication, and other delineations of the industry transforming live animals into meat cuts.

The 1980's brought the term "merger mania" to the beefpacking industry as many of the large firms combined, acquired existing plants, and built new plants. Cargill Inc. purchased MBPXL in 1979 and renamed it Excel Corp. In 1983, Cargill (Excel) purchased a plant from Dugdale and acquired three Spencer Beef plants owned by Land o'Lakes. The purchase was not challenged by the Department of Justice, but Monfort of Colorado challenged the acquisition in the District Court in Denver. Ultimately, the sale of Land o'Lakes plants to Cargill went through. After losing the case regarding the Land o'Lakes plants, Monfort became a part of ConAgra, which also acquired Swift Independent.

Today IBP, ConAgra (Monfort), and Cargill (Excel) dominate in numbers of steers and heifers slaughtered and fabricated and pork slaughter and processing, with National Beef a distant fourth (*Cattle Buyers Weekly*, Sept. 23, 1996. p. 2). ConAgra is also an important poultry processor. Cargill recently sold some integrated poultry operations to Tyson and purchased some of Tyson's pork slaughter plants. The large firms are also rapidly gaining in cow slaughter, including instances where large steer and heifer firms have acquired cow slaughter plants.

Throughout recent decades, the number of meatpacking firms and plants has declined, with smaller plants closing and large plants accounting for more slaughter. In 1974, 1,350 federally inspected plants slaughtered cattle (plus a large number of plants not federally inspected) in the United States; of that number, 850 plants were large enough to report to GIPSA (Grain Inspection Packers and Stockyards Administration, formerly the Packers and Stockyards Administration).[3] By 1997, the number of federally inspected plants slaughtering cattle had dropped to 812 and the number reporting to GIPSA had dropped to 274 (USDA, 1999).

In 1980, 626 plants in 561 firms reported steer and heifer slaughter to GIPSA. In 1996, 211 plants in 174 firms reported. The only size group of steer and heifer plants to increase in number after 1985 is the 1,000,000-head-or-larger category, which increased from 5 in 1986 to 14 in 1996. The increase came primarily from existing plant expansion, not from newly built plants. The 22 plants slaughtering more than 500,000 head per year accounted for about 22.6 million of the 28.6 million steers and heifers slaughtered in 1996.

[3]Plants reporting to GIPSA include federally and nonfederally inspected establishments. Firms purchasing less than 2,000 head of all livestock, or less than 1,000 head of cattle prior to 1977, or less than $500,000 worth of all livestock since 1977 need not report.

Comparing the 1990's With Past Cycles of Cattle Inventories

The previous section summarized a great deal of the mechanics and history of cattle cycles, beef production, beef price spreads, and meatpacker consolidation. This information is helpful in seeing the paths taken by the beef industry to arrive where it is today. We now turn to the more specific objectives of this report, to characterize cattle cycles and price movements to determine whether the cycle of the 1990's was atypically worse than the cattle cycles preceding it in terms of cattle numbers, changes in cattle numbers, prices, price spreads, or changes in prices or price spreads. Also, we determine whether the cattle cycle of the 1990's, in fact, exhibits signs that various segments of the industry are taking unfair advantage of other segments. Specifically, is the cycle of the 1990's characterized by unexpectedly lower returns to cow/calf producers and cattle feeders because of the high level of concentration and continuing consolidation within the beefpacking sector? And, are price spreads an indicator of this alleged exercise of market power?

First, we need to demonstrate whether the cycle of the 1990's exhibits more extreme high or low levels of relevant economic variables than expected, given the behavior of these variables during previous cycles. A review of the literature does not yield many studies that compare specific cattle cycles with other cycles. Crom's study (1981), following the severe cattle cycle of the 1970's, is one of the few studies that characterizes cattle cycles in a statistical sense. Crom identified price, expenditure, and output variables affecting or affected by the amplitude of cattle inventory cycles and estimated the magnitude of their effects. He observed considerable variation in steer prices, retail prices, consumer expenditures per person, and the value of the January 1 cattle inventories. Coefficients of variation ranged from 9 percent (retail prices) to 25 percent (value of January 1 cattle inventory in real dollars), up to 54 percent (consumer expenditures in nominal dollars) for the period 1950-79.

We extended Crom's (1981) general methodology by estimating and comparing variances, coefficients of variation, and means, and by performing other general comparative tests on selected variables. In addition to extending Crom's methodology, we investigated the behavior of cattle and calf inventories and prices by examining correlation coefficients between some more important cattle sector variables.

A question arose during this research about which was more important in affecting cattle inventory behavior, lagged variables as the basis for producers' expectations or future values of variables as expectations. To investigate this question about the role of expectations in inventory dynamics, we included both leading and lagged values of variables in a regression model from which we briefly summarize the results (see box).

Next, we wanted to know if price spreads exhibited unusual behavior during the cycle of the 1990's. Finally, we wanted to know if packer concentration allowed packers to significantly influence cattle cycles. To accomplish these latter objectives, we specified an asymmetric model of farm, wholesale, and retail prices to examine price spreads. With this asymmetric model, we examined price spreads, the relationship between price spreads and the cattle cycle, and the relationship between price spreads and packer concentration. We also used the asymmetric model to simulate expected price movements to see what prices would have looked like over the cattle cycle under a set of restricted conditions.

Data

Data for this study of cattle inventory cycles are annual data and are available back to 1867 for some variables. Almost all variables are available back to 1935, and some are available back to about 1913. In some cases, backcasts were made to extend a data series backward in time, for example, with costs and gross value of production before 1972 (app. table 1). Variables used in the analysis included cattle and hog inventories, farm level prices, cow/calf production costs and gross value of production, value per head, corn prices, various productivity indices, deflators, and other variables.

The prices used in our asymmetric model to explain net-farm, wholesale, and Choice beef retail price movements are from the series ERS uses to calculate price spreads. The Choice beef price spread is a measure of the total difference between the reported price received by producers for a Choice, yield grade 3 live animal (less noncarcass byproducts) and the weighted average price paid for the fresh Choice beef cuts from the animal in retail foodstores. A wholesale boxed-beef value is also calculated such that the total farm-to-retail spread is divided into two component spreads, the farm-to-wholesale spread and the wholesale-to-retail spread. For part of this analysis, the data were transformed so that farm and wholesale prices are expressed in retail weight equivalents. This transformation allowed us to calculate a price spread by subtracting the price at one level from the price at another level.

The Role of Expectations as Drivers of the Cattle Cycle

Producers' expectations about what will happen to them in the context of the cattle industry is one important source of factors affecting aggregate cattle inventory changes. These expectations combined with the biological lags inherent in adjusting cattle inventories have implications for the cattle cycle. The literature is divided on the role that expectations play in the expansion and contraction of beef cattle inventories. There is as yet no clear consensus in the literature about what decisionmakers consider, that is, what is in their information sets and when they make their herd adjustment decisions. Much literature regarding cattle cycles prior to the 1980's cycle rationalized that higher current and past cattle and calf prices motivated heifer retention for herd building (for example, Jarvis, 1974; Arzac and Wilkinson, 1979, p. 307; and Nelson, 1984). That is, these authors rationalized that high prices observed in the current period would motivate heifer retention and inventory buildup. However, other authors, especially since the 1970's cycle, suggest a somewhat reverse mode of expectation formation by looking into the future (Rucker, Burt, and LaFrance, 1984; Trapp, 1986; Rosen, Murphy, and Schienkman, 1994). Trapp (1986, p. 702), in his simulation of optimal herd dynamics, emphasized the role of expectations when he suggested that, in practice, the optimal "[c]ulling and replacement strategies must anticipate the feeder cattle price cycle by some four to six years." Indeed, Trapp (1986, p. 700) observed that "the most rapid rebuilding phase for the herd occurs when profit per head is lowest or even negative." He found negative returns for the first 3 years of his simulated feeder cattle price cycle, during the expansion phase of the simulated cattle cycle, and that "[t]he optimal herd size exhibits cyclical patterns that peak and bottom three years ahead of the feeder steer price cycle" (p. 700).

Using leading values of variables as expectations variables is related to rational expectations and is referred to as "implicit expectations" (Mills, 1957, and Lovell, 1986). According to Lovell (1986), Mills' (1957) implicit expectations differ from rational expectations through the assumption that the prediction error term is assumed uncorrelated with the actual realization, whereas Muth's (1961) rational expectations assumes that the error term is uncorrelated with the predicted value.

We found no clear evidence in the literature suggesting that leading variables are better at describing inventory behavior than lagged variables or vice versa. In related work only briefly reported here, we examined directions of causality, using correlation analysis, as above, and regression techniques. We found that leading variables have more explanatory power than lagged variables, but lagged variables appear to have larger effects on cattle and calf inventories. Generally, the leading variables were more significantly different from zero than were the lagged variables, but the lagged variables had slightly larger parameter esimates. The coefficient for current cattle prices per hundredweight was significant and negatively related to cattle and calf inventories, indicating that high prices in the current period may result in sales of cattle and low prices may result in cattle being held off markets. This result supports the idea that producers are motivated to sell cattle during periods of high prices rather than retaining them for purposes of herd expansion. Current and expected corn prices had a generally positive effect on current cattle and calf inventories, while lagged prices had no significant effect in our simple model. Inventories are often thought to depend on the number of calves born in previous periods, so it was surprising that the size-of-calf crop variables had no effect on cattle and calf inventories.

Statistical Comparisons of Cycles

Our first formal hypothesis was that the cycle of the 1990's was no worse than any other previous cycle.[4] We set up a hypothesis of "no worse than" (a null hypothesis) because it is easier to reject something (like "no worse than") than it is to try and prove the opposite ("is worse than") is true. That is, if we can demonstrate evidence for some difference, then we can reject our null hypothesis of "no difference" without necessarily knowing exactly what makes the difference. More specifically, if we can demonstrate some evidence that the 1990's cycle is not the same as other cycles, then we can reject our null hypothesis. If we can reject our null hypothesis, we can say there is evidence to support the contention that the cycle of the 1990's is somehow different than previous cycles. In some cases, we examined the entire data series, while in other instances, we examined each cattle cycle or specific statistics for each cattle cycle taken across cattle cycles. For instance, we examined the mean of real net returns above cash costs over the period 1913-90 and the mean of individual cycle means.[5]

Means, Variances, and Coefficients of Variation

The first question we asked was, how did cow/calf producers fare during the cycle of the 1990's and during previous cycles? The average (mean) per-cow real net returns above cash costs for the 1913-1990 series was $56.18 in 1982-84 dollars. Looking at cycle statistics, the mean real net returns above cash costs for the eight cattle cycles before the 1990 cycle was $52.66 in 1982-84 dollars. The mean for the 1990's cattle cycle, through 1997, was $17.46, well within a 95-percent confidence interval (-$14.40, $119.70) based on the series variance. Variability, measured by the coefficient of variation (ratio of the standard deviation to the mean of a variable) of real net returns for the first 6 years of the current cattle cycle is 2.587. The series coefficient of variation for before 1990 is 1.012. The coefficient of variation for means of real net returns for the last eight cattle cycles before 1990 is 0.64.

As a further test, we wanted to know if there was a difference in how real net receipts above cash costs varied over cycles before 1968, the last year of the cycles preceding the 1970's, and cycles from 1968 to the present. Net returns above cash costs and their cyclical averages have trended downward, which is later discussed. However, a simple F test (ratio of variances) of variances of real net receipts above cash costs between the three consecutive cattle cycles ending in 1967 (variance of 194.12) and the three consecutive cycles beginning in 1968 (variance of 198.05) did not show a significant difference in variability between the two periods.

Cattle price volatility is another way the situation could be worse during the cycle of the 1990's. However, real (1982-84 dollar) cattle prices appear less volatile relative to their means than real net returns. The mean real cattle price per cwt for the period 1935-96 was $66.55. A 95-percent confidence interval around the mean of $66.55 encompasses an interval from a high of $97.50 to a low of $35.61. No annual real average price per cwt was below lower bound of the 95-percent confidence interval, although there were two instances where high prices were higher than the upper bound of the 95-percent confidence interval. The lowest real price was $37.41 in 1996. Prices in 1950 and 1951 (the year of the highest average real price, $114.19) were higher than the upper bound of a 95-percent confidence interval. The variance for prices over the same period was 239.4049 (standard deviation the =15.4727), yielding a coefficient of variation of 0.2325.

All actual values of per-capita pounds of beef and veal consumption on a carcass-weight basis were within the 95-percent confidence interval bounds. The highest per-capita beef and veal consumption was 131.5 pounds in 1976, the lowest, 61.5 pounds in 1943.[6] Per-capita consumption showed relatively low volatility, with a coefficient of variation of 0.21.

[4]"Worse" in this context means "adversely affecting" cattle producers, such as returns below some lower bound of a confidence interval, or inventories above some upper bound.

[5]We will distinguish between the two sets of statistics by calling the statistic for an entire series the series statistic and the statistic across cycle subseries statistics the cycle statistic.

[6]Per capita beef and veal consumption was lower in 1932, at 53.3 pounds, but outside the data range of this specific analysis.

Relative Changes in Selected Variables from Previous Cattle Cycles

Real net receipts above cash costs during 1996 (the second lowest real net receipts above cash costs since 1913) were -$48, just over half the -$79 loss observed in 1975, but within a 95-percent confidence interval of annual real net receipts. Real net receipts above cash costs have trended downward since 1913 (simple regression slope of -1.17613, t-statistic of -5.3), as has the average per cycle of net receipts above cash costs over the last eight cattle cycles (slope = -10.7891, t-statistic = -3.16).

The longest string of consecutive years with negative real net receipts above cash costs occurred from 1981 through 1986, exceeding the series of losses from 1974 through 1977 and 1995 through 1996. April 1997 calf prices were $91 per cwt, roughly 53 percent higher than April 1996's $59.30 (USDA, *Livestock, Dairy and Poultry Situation and Outlook*, April 16, 1997). Cow prices in April 1997 were, however, $39 per cwt, only 13 percent over April 1996's $34.44. Percentage changes in cattle and calf prices from April 1996 to April 1997 for other weights and classes of cattle were between these extremes, suggesting that nominal and real net receipts above cash costs for 1997 will be positive.

Several factors help account for differences in the severity of the last three cattle cycles. President Nixon's beef price freezes, oil price shocks, drought, and extremely high grain prices compounded the adjustment in cattle numbers in the 1970's. The peak in cattle inventories during the cattle cycle of the 1970's was also the historical peak in cattle inventory numbers. Both subsequent cattle cycles peaked at inventories substantially below the 1975 peak (fig. 1). In fact, the inventory peaks for the two cattle cycles since the 1970's have been successively lower. However, these successive declines in cattle inventory numbers have been at least partially offset by a shift in beef cattle production technology that increased average pounds of beef produced per cow per year. Beef produced per cow has increased more than 100 pounds per cow since the first half of the cycle in the 1980's. Total annual beef production has remained over 25 billion pounds per year since 1994. It peaked at 25.7 billion pounds in 1998, the same as in 1976. The ability to produce more beef with fewer cows precipitated adjustments in cattle numbers during the previous and current cattle cycles. This is because fewer cattle are needed to produce the same amount of beef. Drought also occurred in the 1980's and in 1996. The improved technology combined with the 1996 combination of drought and high grain prices compounded the adjustment in cattle inventories during the mid-1990's.

At the same time that cattle cycles seem to be generating years of greater losses in real dollars, annualized rates of increase in cattle numbers from the beginning of each cattle cycle expansion to the cyclical peak in cattle numbers appear to be declining. During earlier cycles, cattle numbers increased at an average annual rate of 4 percent or more. During the last two cycles, expansions occurred at a 1.2-percent annual rate. This decline in the rates of increase in cattle numbers suggests that cattle producers may be becoming more astute at adjusting herds in the face of the cattle cycle. Information, including price and demand information, is more widely and readily available and perhaps is being used in herd management decisions.

Most of the last eight cattle cycle expansions have taken 6 to 8 years from low to peak. The shortest expansion, taking only 3 years from low to peak, was during the 1980-90 cycle. In addition, cattle numbers have increased between 17 and 30 percent from each cycle's low in numbers to its peak, with only two exceptions: the cycle of 1980-90 and the current cycle. The percentage increase from 1980-82 was just under 4 percent, and for the current cycle that began in 1991 was just under 8 percent. While these rates of buildup look somewhat erratic, a glance at total beef production shows an increase of almost 14 percent from low to peak for the 1980's cycle and just over 12 percent for the 1990's cycle. Also, beef production peaked at 24.2 billion pounds during the 1980's cycle, in line with trends in beef production for previous cycles and the 1990's, but excluding the huge jump in beef production during the cycle of the 1970's.

Many papers have been written suggesting ways to overcome or take advantage of cycles in livestock production, but the beef cattle cycle persists. There are at least two reasons why beef cattle cycles may persist: One, the very seasonal production technology may force producers to postpone adjustments in breeding herds. Two, other than military meat procurement and school lunch program purchases, there are no government programs, support prices, or other policy interferences with the beef cattle markets. Therefore, there is no way to assess prices in future periods with any degree of certainty as there was with target prices and other fiat prices that, in the past, provided price floors for grains. It is interesting to observe that dairy cow numbers are not behaving cyclically, having ceased robust cyclical behavior during the 1970's.

Correlations

Correlations tell us how closely variables move together. Correlations can suggest causal relationships. In our study, correlation coefficients between cattle cycle variables yielded some interesting results (table 1), not all of which were as one would expect given price-quantity relationships suggested by economic theory. The correlations observed with the highest t-values were between per-capita beef and veal consumption and cattle and calf numbers, between per-capita red meat consumption and cattle and calf numbers, and between changes in per-capita red meat consumption and cattle and calf numbers.

All correlations between various measures of final products could be expected to vary from a strict one-to-one accounting correspondence because of substitution between species meats and because of some slippage due to imports and exports. At 0.95 (t value = 24.08 (Ezekiel, 1930, p. 256)), the positive relationship between per-capita beef and veal consumption and cattle and calf numbers was the highest and most statistically significant observed correlation and was close to the one-to-one relationship one might expect. There is not a lot of leeway in capacity to store beef once cattle reach slaughter weight or after they have been slaughtered, even when frozen. The second highest correlation, also related to per-capita consumption was the 0.95 (t value = 23.16) for per-capita beef and veal consumption and total per-capita red meat consumption. Following closely was the 0.93 (t value = 19.17), measuring a direct relationship between total cattle and calf inventories and total per-capita red meat consumption.

Given constant costs or costs that steadily increase or decrease, one could expect close to a one-to-one relationship between returns and output prices. Real returns per cow and cattle prices in real dollars per hundredweight were correlated at 0.93 (t value = 18.85). Real receipts per cow were also correlated with real dollars per hundredweight, 0.81 (t value =10.47). This less than perfect correlation is due to fluctuations in feed prices, oil prices, interest rates, and prices of other inputs. The correlation between the change in net returns above cash costs and the change in cattle numbers was -0.52 (t value = -4.67). This negative correlation between the change in net returns above cash costs and the change in cattle numbers would seem to support Trapp's (1986) observation that simulated cow herd expansion optimally occurs during periods of negative returns.

Economic theory leads one to expect an inverse relationship between quantities and prices, but modified somewhat by quantities and prices of substitutes and complements. The correlation between changes in cattle and calf numbers and changes in cattle price per cwt was at -0.45 (t value = -3.89), again the expected inverse relationship, but not as large as expected, given the changes in farm level income observed in the data and given the causality arguments encountered in some of the earlier literature and the popular press.

Table 1--Correlation coefficients and t-statistics for cattle cycle variables, 1935-96

Variable	All hogs and pigs	Per-capita beef and and veal consumption	Costs per cow	Total cattle and calves	Change in cattle and calf inventory from previous year	Change in net income above cash costs from previous year	Change in corn price from previous year
Per-capita beef and veal consumption	-0.0342 (-.26)						
Costs per cow	.2615 (2.08)	0.1483 (1.15)					
Total cattle and calves	.1061 (.82)	.9527 (24.1)	0.3031 (2.44)				
Change in cattle and calf inventory from previous year	.3623 (2.99)	-.2311 (-1.82)	.0096 (.07)	-0.0460 (-.35)			
Change in net income above cash costs from previous year	-.1216 (-.94)	.0047 (.04)	-.0872 (-.67)	-.0982 (-.76)	-0.5200 (-4.67)		
Change in corn price from previous year	.1883 (1.47)	-.0502 (-.39)	-.0911 (-.70)	-.0312 (-.24)	.1879 (1.47)	0.1333 (1.03)	
Change in per-capita beef and veal consumption from previous year	-.0748 (-.58)	.0414 (.32)	-.0504 (-.39)	.0517 (.40)	.4229 (3.58)	-.4480 (-3.84)	0.1771 (1.38)
Change in cattle price per hundredweight from previous year	-.0222 (-.17)	-.1439 (-1.12)	-.0135 (-.10)	-.2168 (-1.71)	-.4510 (-3.89)	.7878 (9.82)	.0944 (.73)
Total red meat per-capita consumption	.2187 (1.74)	.9492 (23.16)	.2015 (1.58)	.9283 (19.17)	-.1130 (-.87)	-.0480 (-.37)	-.0002 (-.001)
Net returns above cash costs per cow	.3288 (2.67)	-.5398 (-4.93)	.2236 (1.76)	-.5276 (-4.77)	-.0160 (-.12)	.3991 (3.34)	.1813 (1.42)
Corn price	.1290 (1.00)	-.5199 (-4.67)	.4094 (3.45)	-.4093 (-3.45)	.2438 (1.93)	-.0220 (-.17)	.3072 (2.48)
Per-capita pork and lamb consumption	.7614 (9.02)	-.3413 (-2.79)	.1307 (1.01)	-.2536 (-2.01)	.3961 (3.31)	-.1570 (-1.22)	.1591 (1.24)
Year	.0441 (.34)	.7482 (8.66)	-.0257 (-.20)	.7194 (7.95)	-.2250 (-1.78)	-.0650 (-.50)	-.0360 (-.27)
Real gross receipts per cow	.3773 (3.13)	-.3957 (-3.31)	.5749 (5.40)	-.3256 (-2.65)	-.0100 (-.07)	.3013 (2.43)	.1170 (.90)
Real price of cattle per hundredweight	.3180 (2.58)	-.1637 (-1.27)	.7044 (7.62)	-.0525 (-.40)	.1849 (1.44)	.1457 (1.13)	.0307 (.24)

Continued--

Table 1--Correlation coefficients and t-statistics for cattle cycle variables, 1935-96--Continued

Change in per-capita beef and veal consumption from previous year	Change in cattle price per cwt	Total per-capita red meat consumption	Real net returns per cow	Real price of corn	Per-capita pork consumption	Year	Real receipts per cow
-0.6620							
(-6.79)							
.0637	-0.0540						
(.49)	(-1.20)						
-.3560	.4922	-0.4250					
(-2.93)	(4.34)	(-3.61)					
.2411	.1018	-.4380	-0.4628				
(1.91)	(.79)	(-3.75)	(4.01)				
.0587	-.0020	-.0280	-.4439	0.3420			
(.45)	(-.02)	(-.22)	(3.80)	(2.80)			
-.1570	-.1540	.6788	-.4390	-.7590	-0.3490		
(-1.22)	(-1.20)	(7.10)	(-3.75)	(-8.95)	(-2.86)		
-.3190	4080	-.2790	.9261	.5470	.4232	-0.3784	
(-2.58)	(3.43)	(-2.23)	(18.85)	(5.02)	(3.59)	(-3.14)	
-.2330	.3239	-.0540	.6537	.5231	.3573	-.3675	0.8064
(-1.84)	(2.63)	(-.42)	(6.33)	(4.71)	(2.94)	(-3.04)	(10.47)

Price Spreads and the Cattle Cycle

Producers note that the farm value share of the Choice beef retail price declined from nearly 70 percent in the 1970's to below 50 percent in 1996 (figs. 3 and 4). During the same period, the nominal farm-to-retail price spread widened from less than 40 cents per pound to over a $1.40 per pound (figs. 3 and 5). Many producers believe these figures indicate improper pricing behavior by marketing firms, especially beefpackers. However, previous studies have found conflicting evidence to support such contentions (see next chapter, "Concentration Measures for the Beef Packing Industry").

Long-Term Fluctuations

Looking at nominal price spread data versus deflated price spread data gives a different perspective on long-term price spread patterns. On a nominal basis, wholesale-to-retail and farm-to-wholesale price spreads for Choice beef have increased dramatically since the 1970's (figs. 3 and 5).

But when adjusted for inflation, the wholesale-to-retail spread has fluctuated within a relatively constant band, while the farm-to-wholesale spread has declined substantially (figs. 5 and 6). The services provided by beefpacking firms (processing and packaging) have increased over time, and the cost of those services has risen.

The index of food marketing costs, a measure of changes in the costs of marketing inputs such as labor, packaging, transportation, energy, and other inputs, increased four-fold from 1968 to 1994, from 103.5 to 435.0 (Elitzak, 1998). The farm value share is low, partly because marketing cost changes have paralleled inflation while cattle price changes have not. Decreasing farm value share is a characteristic of most agricultural commodities and signifies to some extent improved technological efficiencies. The farm value share for all U.S. domestically produced farm foods was 40 percent in 1952, 33 percent in 1960, 32 percent in 1970, 31 percent in 1980, 24 percent in 1990, and 21 percent in 1997 (http://www.econ.ag.gov/briefing/foodmark/cost/data/bill/value.htm).

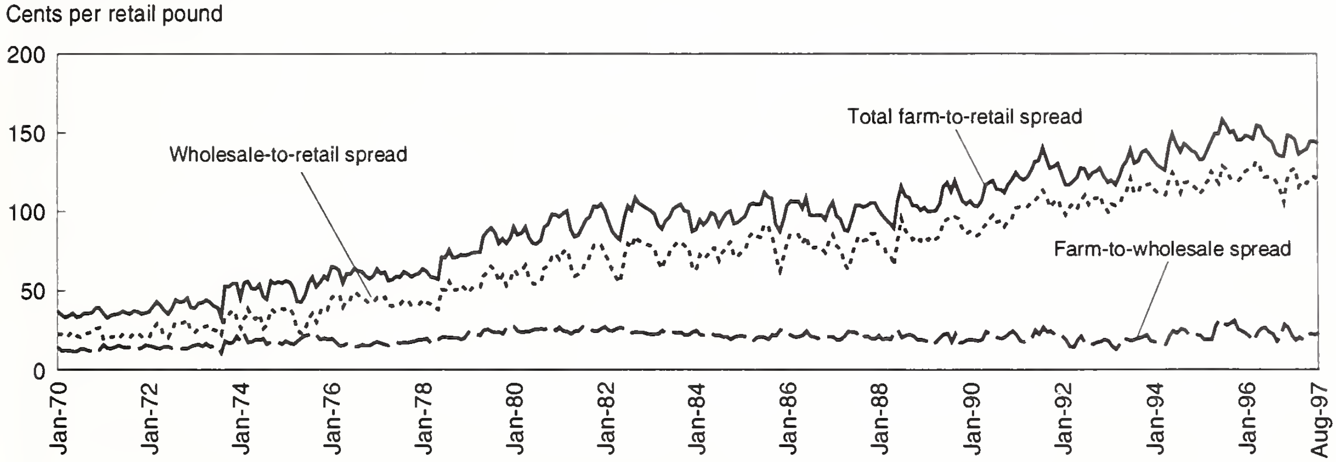
Short-Term Fluctuations

Short-term fluctuations in beef price spreads stem largely from the lag observed between price changes at the farm and retail levels. Retail prices are more rigid than commodity prices at least partly because retailers set prices for advertising purposes weeks ahead, and because they believe consumers prefer more stable prices.

ERS research shows that price adjustments at farm and wholesale levels are nearly concurrent using monthly data (fig. 7). The retail price follows price changes at the farm and wholesale levels with a lag distributed over almost a year. Retail price adjustments are asymmetric (upward movements in farm prices are followed about 24 percent more quickly at retail than are downward price movements). Retailers possibly expect that downward movements are likely to be temporary and wish to avoid marking prices down then back up again. This asymmetry provides one justification for our asymmetric model of price changes described in a later section and in Appendix B.

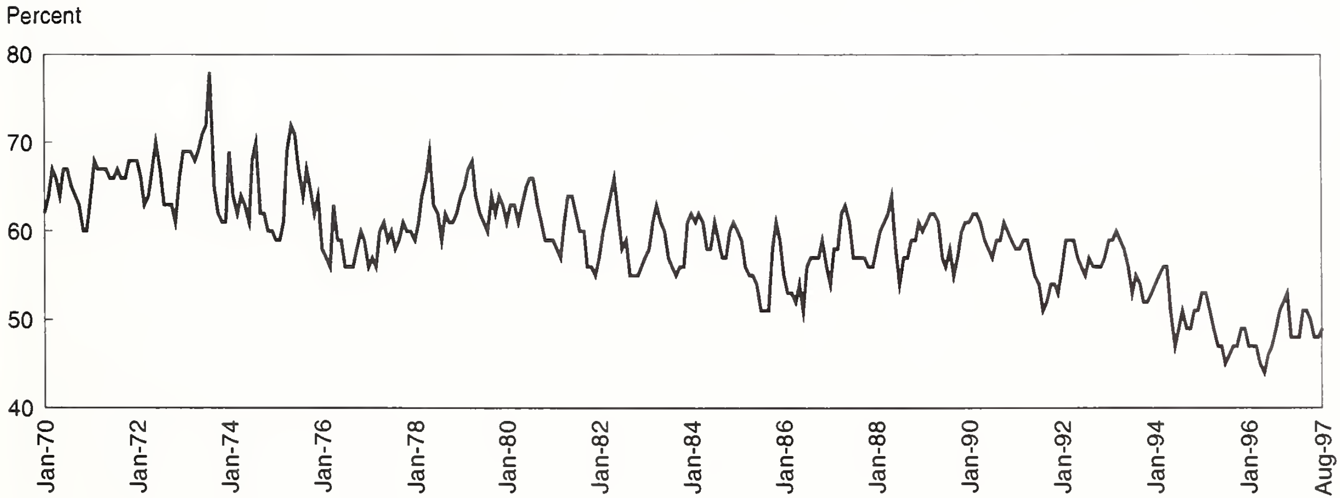
For example, from April to May of 1994, the net farm value of Choice beef declined 15 cents, the wholesale value dropped about 9 cents, and the retail price went up about 1 cent. In May and June, the net farm value dropped another 12 cents, the wholesale value again fell 9 cents, and the retail price moved down about 5 cents. The retail price continued to decline through August, even though farm and wholesale prices increased in July and August. As a result of the lags in price changes at the retail level, the spread tends to widen in the short term when prices are falling, and narrow, but to a lesser extent, when prices are rising.

Figure 3
Farm-to-wholesale, wholesale-to-retail, and total price spreads for beef (Choice, yield grade 3), January 1970-August 1997



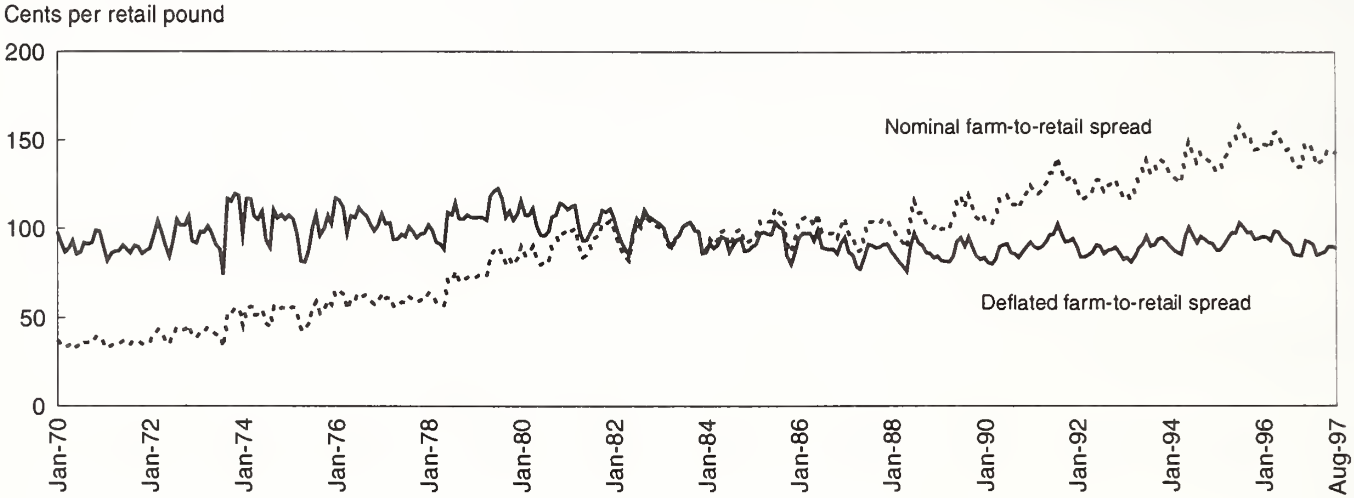
Note: Average by month, January 1970-August 1997.
Source: USDA, ERS.

Figure 4
Farm share of retail price for beef (Choice, yield grade 3), January 1970-August 1997



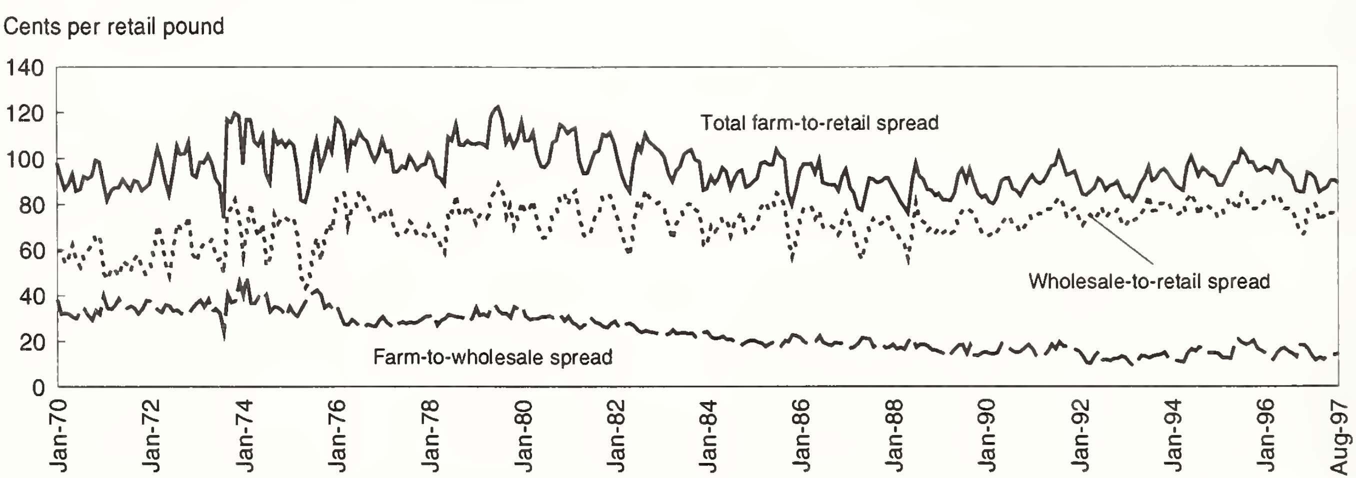
Note: Average by month, January 1970-August 1997.
Source: USDA, ERS.

Figure 5
Farm-to-retail spreads, nominal and deflated, for beef (Choice, yield grade 3), January 1970-August 1997



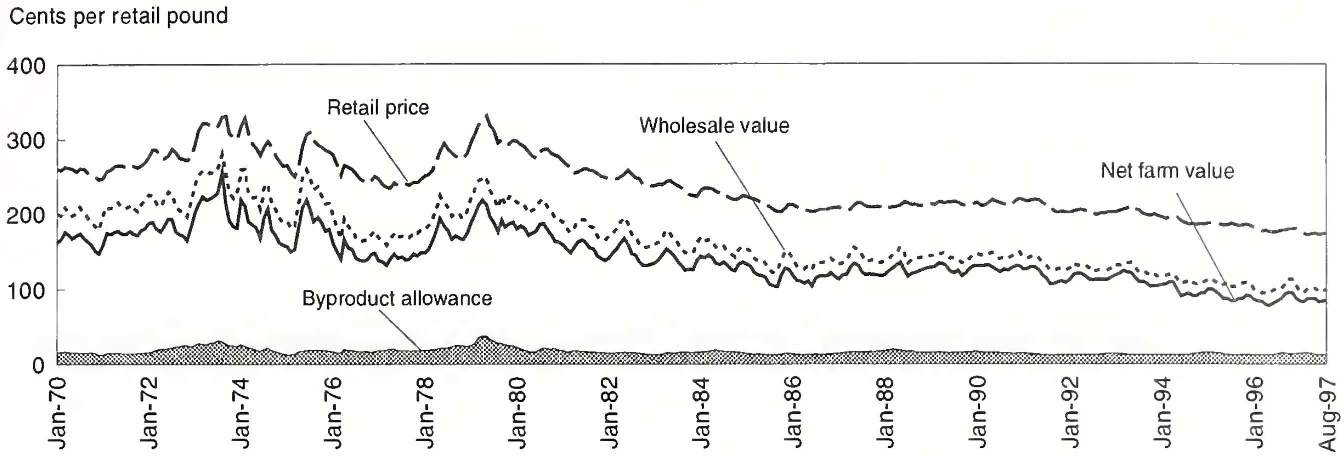
Note: Average by month, January 1970-August 1997. Deflator is Consumer Price Index, United States, all urban, all items, 1982-84=100.
Source: USDA, ERS.

Figure 6
Farm-to-wholesale, wholesale-to-retail, and total price spreads: Deflated prices for beef (Choice, yield grade 3), January 1970-August 1997



Note: Average by month, January 1970-August 1997. Deflator is Consumer Price Index, United States, all urban, all items, 1982-84=100.
Source: USDA, ERS.

Figure 7
Retail price, wholesale value, net farm value and by-product allowance: Deflated prices for beef (Choice, yield grade 3), January 1970-August 1997



Note: Average by month, January 1970-August 1997. Deflator is Consumer Price Index, United States, all urban, all items, 1982-84=100.
Source: USDA, ERS.

General Structure of a Price Spread Adjustment Model

We address several issues concerning price spreads, cattle cycles, and packer concentration, especially for the 1990's cattle cycle, to respond to the allegations that packers (because of their alleged market power) and the 1990's cycle had an extremely adverse effect on producers. One issue is whether prices and price spreads change at the same rate when prices are increasing as when prices are decreasing (asymmetry of price and price spread behavior). A second issue is whether there was an unexpected shift in prices during the 1990's cattle cycle. A related third issue is the effect that the cattle cycle had on price spreads. A fourth issue is the effect of packer concentration on price and price spread behavior. This section addresses the first three issues. The fourth issue is discussed in the next chapter with the use of the asymmetric model.

To examine the first three issues, we needed a model of prices and price spreads that would allow us to explain what happens to farm-, wholesale-, and retail-level prices and price spreads.[7] Economists have estimated many models where the farm price moves first and drives the wholesale price, which in turn drives the retail price. One advantage of these traditional models is that, if the other prices are following the farm price, economists interested in explaining price spread movements do not have to worry about why the farm price changes, they have only to track how the other two prices react to the farm price. We estimated these effects and effects of the cattle cycle on price spreads by using an asymmetric, endogenous switching model that indirectly explains price spreads. Price spreads are modeled indirectly by first explaining movements in farm, wholesale, and retail prices of cattle and beef. Once we have explained the movements of these three prices, we indirectly explain the spreads between these prices.

The asymmetric model we developed for this report (see Appendix B) was based on previous research on price interactions in pork and beef markets (Hahn, 1989 and 1990). The model was designed to be flexible and to allow the past history of price spreads to determine as much of the outcome as possible. The model allowed price interactions to be either very simple or very complex. Not only can it take time for prices to adjust to changes in market conditions, but the speed at which they adjust can change, depending on the direction they are going. In our case, the endogenous variables that we explain are the net-farm, wholesale, and retail beef prices.

[7]Variables are natural logarithms of underlying variables. A "change" in prices is a difference in logarithms of two successive prices. The logarithm of a negative number is undefined.

Our model, like the traditional models, allows for slow price transmission from one level of the market to another. That is, it allows, though it does not require, retail price adjustments to lag behind wholesale price changes. However, we made our model more flexible in that we did not prespecify one price as the leader and the others as followers. Instead, our model allows the retail, wholesale, or farm price to drive the others, letting the data pick the leading price variable. Our model also allows for the case in which all three prices interact simultaneously. This extra flexibility requires that our model also have the ability to explain the general level of prices as well as their spreads.

The switching part of the name describes the ability of the model's algebraic coefficients to change, depending on the direction the variables are going. If increasing price coefficients are the same as decreasing price coefficients, then the relationship is symmetric. If, however, increasing prices can have different coefficients than decreasing prices, then the relationship is asymmetric, hence, the asymmetric part of the descriptive name for our model.

As we mentioned earlier, one of the notable features of beef prices is that farm and wholesale prices are more volatile than retail prices. Also, it often appears that retail prices follow farm and wholesale prices, with a lag of about a month. That is, retail prices tend to go up a month or more after the others go up and drop a month or more after the others drop. Retail prices will follow wholesale prices if it takes time for retail prices to adjust to changes in the wholesale price.

The real world is more general than most models would suggest. In addition to determining prices, the beef market also determines beef production and allocates product to domestic and international markets. Our model focuses only on prices at three levels of the beef marketing chain. Our model is based on the assumption that we can pull the pricing parts of the market out of the system as a whole and study their effects. The rest of the marketing structure is collapsed into the terms that determine the target price spreads and levels.

We assume that the longrun price level is determined by other, more general, supply and demand factors. We model these effects using information on supplies of beef and pork, consumption of beef, pork, chicken, and turkey, and on other variables that shift the demands for and supplies of meats. The supply and demand shifters include seasonality and trends, including technological change. Our explanation of long-term price spreads is relatively simple. We assume that these grow with inflation along their longrun trend. This assumption is consistent with what we think we see in the raw data (see the discussion above on long-term fluctuations).

The shortrun effects of supply and demand shifts on prices will vary from the longrun effects unless the model has complete, not partial, adjustment. In addition to the effects of partial adjustment on prices, shortrun and longrun effects can vary for other reasons, particularly if there is some shortrun feedback from price changes to quantity changes. This type of feedback seems particularly likely, especially between prices and demand.

To help differentiate between the shortrun and longrun effects of the other variables, we divided most of our explanatory variables into two parts, the change from the previous month (shortrun elasticities) and last month's value (longrun elasticities). This month's value is the sum of those two parts. Our explanatory variables also include intercepts, trends, and seasonal factors; for mathematical reasons, these intercept shifters cannot be meaningfully split into this month's change and last month's value. (Knowing last month's value is the same as knowing this month's value for these terms. Knowing last month's beef production is helpful in predicting this month's production, but there is still plenty of room for surprises.) A complete list of explanatory variables and their parameter estimates can be found in table 2. Except for the intercept, trends, and seasonal factors, the explanatory variables we used are the natural logarithms of the underlying variables.

We used the monthly consumer price index (CPI) to factor out inflation in current price changes and lagged prices. The farm, wholesale, and retail prices of beef were also divided by the average value of the deflated retail price. By doing this, the coefficients of the supply and demand variables could be interpreted as elasticities at the retail price level.

Table 2--Asymmetric Model Estimates, equations

Variables	Price level	Farm-to-wholesale spread	Wholesale-to-retail spread
Increasing endogenous:			
Retail	0		2.6951
Wholesale	2.9796	3.9760	0
Net farm	0	-3.5088	
Decreasing endogenous:			
Retail	.9686		3.5528
Wholesale	3.6695	4.5720	-.0903
Net farm	.0381	-3.6091	
Lagged endogenous variables:			
Retail	-.7573		-1.0000
Wholesale	0	-1.0000	1.0000
Net farm	-.2427	1.0000	
Exogenous variables:			
Intercept	1.2745	.1327	.3518
Intercept shift	.0790	.0176	.0367
Trend	-.0511	-.0047	-.0022
Seasonal effects (these are constrained to sum to zero):			
January	.0122	.0053	.0058
February	-.0234	-.0226	-.0057
March	-.0180	-.0234	-.0073
April	.0130	.0117	.0071
May	.0074	.0291	.0173
June	-.0276	.0044	.0104
July	-.0312	-.0174	-.0031
August	.0016	-.0070	-.0106
September	.0153	.0059	-.0117
October	.0061	.0004	-.0097
November	.0143	.0005	-.0010
December	.0303	.0130	.0086
Shortrun elasticities (at the mean, deflated retail price):			
Per-capita beef disappearance	.2249	.1387	.0540
Per-capita pork disappearance	.5129	.2084	.0235
Per-capita chicken disappearance	.3498	.0025	.0650
Per-capita turkey disappearance	.0382	.0154	.0140
Commercial beef production	-1.0335	-.2152	-.3527
Commercial pork production	-.3046	-.1521	.1471
The CPI for food	4.9675	.6917	2.7809
Per-capita consumption expenditures	-.8363	-.4459	-.7186
The price of corn	-.0383	.0518	.0321
The price of soybean meal	.1338	.0801	.0285
The price of hay	.1814	.0533	.1016
Longrun elasticities (at the mean, deflated retail price):[1]			
Per-capita beef disappearance	-.5608		
Per-capita pork disappearance	-.4153		
Per-capita chicken disappearance	.5003		
Per-capita turkey disappearance	-.0025		
Commercial beef production	-.0555		
Commercial pork production	.3235		
The CPI for food	.4506		
Per-capita consumption expenditures	.4133		
The price of corn	.0076		
The price of soybean meal	.0153		
The price of hay	.0518		

[1] The "elasticities" do not correspond to either demand or supply elasticities. They are a combination of both.

Estimation Results and Interpretations

Estimating endogenous switching models is difficult because they are not included in standard econometric software. They can be estimated using general mathematical optimization software. We set up the equations that we estimated for the convenience of the software we used, General Algebraic Modeling System (GAMS), and also to make it easier to impose coherent (sensible) parameter values. We estimated our model using maximum likelihood estimation and monthly data, previously described, beginning in 1979, and running to the end of 1996.

One disadvantage of using optimization software is that it does not provide us with measures of the standard errors of individual coefficients, so we have to use tests that do not depend on parameter standard errors. We used likelihood ratios to test two hypotheses, one for asymmetry of price behavior, and a second for a recent shift in price behavior.

The first test was for the importance of asymmetry. In previous work, Hahn (1989 and 1990) found that pork and beef prices generally responded asymmetrically. That is, they reacted more quickly when they were going up than when they were going down. In the current study, our test for asymmetry was significant at the 3-percent level. We concluded that asymmetry was important, and prices move up faster than they move down.

The second test arose from concern that recent cattle prices have been lower than expected. We added a dummy variable to each equation to capture shift in pricing in the last 5 years of the sample (1992-96, inclusive). These three dummy variables, tested as a group, had a huge test statistic. The odds of observing such a number by chance would be less than 1 in 10,000. We accepted the hypothesis that there has been a shift in cattle pricing (or technically speaking, we could not reject the null hypothesis of no shift in cattle pricing), but the shift was upward, not downward as the allegations motivating this study suggested. In other words, prices were actually higher during the last 5 years than previous behavior suggested they should have been. Our estimates of the asymmetric model with pricing (intercept) shifts are in table 2.

As noted before, the behavior of the estimated model can switch depending on the direction each price is heading. With three prices and two directions for each, there are eight possible combinations of price directions. The model is relatively easy to interpret when the farm and retail prices are increasing. In the two cases where the farm and retail prices are going up and the wholesale price is going in either direction, the model can be rearranged to get a wholesale-led model, that is, one where prices are determined in steps.

When the farm and retail prices are increasing, their coefficients in the price-level equation are zero. When the farm and retail prices are increasing, only the wholesale price can react to move the general price level closer to its target. Once the wholesale price reacts, the farm and retail prices adjust. The farm price is determined by the farm-wholesale-spread equation and the retail price by the wholesale-retail-spread equation. Increasing and decreasing wholesale prices have positive coefficients in the farm-wholesale equation. This means that current price changes at wholesale cause current price changes at the farm. The wholesale price tends to move the farm price in the same direction. With farm-price coefficients smaller (in absolute value) than either wholesale price coefficient, these estimates (inverses of estimated parameter effects) imply that the farm price tends to overreact to wholesale price changes. A 1-cent change in the wholesale price tends to cause a greater change in the farm price.

Wholesale-price decreases have a small coefficient in the wholesale-retail spread equation, while wholesale price increases have a zero coefficient. This means that current wholesale price decreases have little effect on this month's retail price. Wholesale price increases have no effect on this month's retail price.

When either the farm or retail price is decreasing, the estimates imply more complex behavior. For instance, the wholesale price is affected by the farm price change in the price-level equation, while the farm price is affected by

the wholesale price in the spread equation. When the retail price is decreasing, it also appears in the price level equation. As a result, none of the three prices can be selected as leading the others. When all three prices are declining, all three react to move prices closer to the target level, and all three end up being affected by the difference between actual and target spreads. Additional analysis of the three coefficients indicated that, in the short run, the wholesale price is the most sensitive to differences between target and actual price levels. More generally, while the wholesale price has an important role in getting the general price level right, its lagged value is not a factor in calculating the lagged, general price level. Its estimated coefficient is not statistically different from zero. Also, the retail price, which has very little direct response (often none) to the price level, has a very high weight.

Simulations and Forecasts With the Asymmetric Model

We used our asymmetric model to simulate and forecast prices and spreads to examine the issues of a shift in the behavior of recent prices and the effect of cattle inventory cycle behavior on price spreads.

Beef/Cattle Price Shifts

As noted above, our estimates imply that there was an important shift in the behavior of the system in the past 5 years, but it was actually a shift in favor of cattle producers. We simulated two sets of price forecasts to evaluate the pattern of beef prices in the last 3 years of our sample. These forecasts can be seen in figures 8, 9, and 10. The first set of forecasts used coefficients based on all the data, 1979-96. These are the in-sample forecasts.

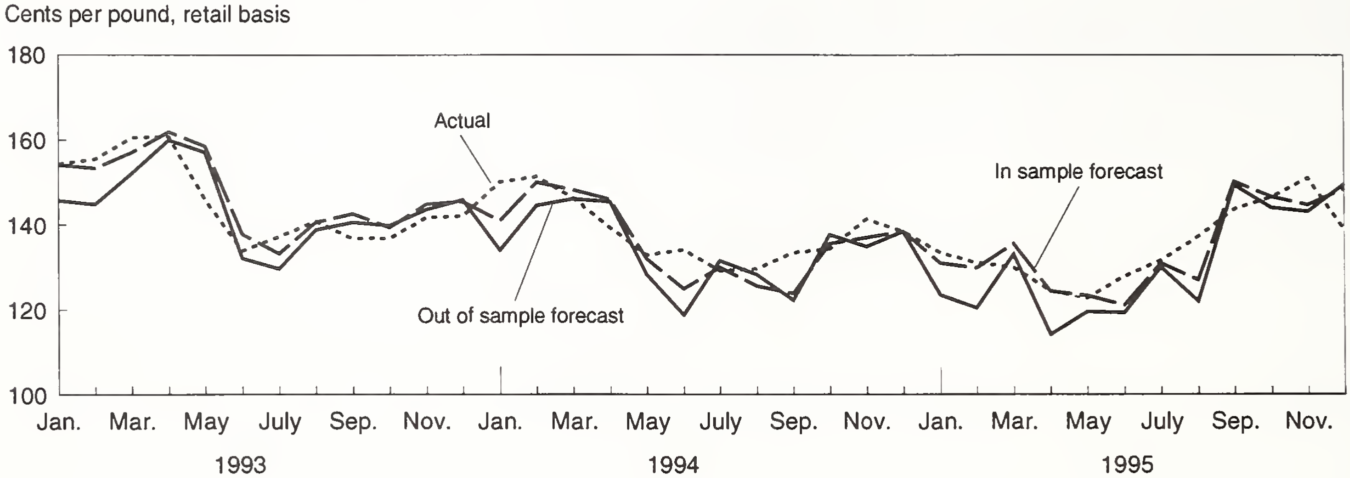
The shift in cattle pricing in the last 5 years caused cattle, wholesale, and retail beef prices to be higher than they would have been given their earlier pattern of reaction to supply and demand shocks. On average, farm and wholesale prices are 6.6 cents per retail-pound equivalent higher than they would be without the shift, and retail prices are 3.8 cents per pound higher. The farm-wholesale price spread has been unaffected by the shift, and the wholesale-retail spread has dropped. The out-of-sample forecasts are based on the coefficients estimated, using only the 1979-91 data. Note that the out-of-sample forecasts are generally lower than in-sample forecasts, further evidence that the recent shifts in the system led to higher prices.

We simulated beef prices under a series of alternative scenarios to see the effects of changes in selected scenarios on beef price spreads. Starting with January 1991, we simulated beef prices given: fixed beef production and consumption, fixed pork consumption and production, and fixed production and consumption of chicken and turkey. All other explanatory variables in the model were fixed.

Like all econometric models, ours deals mostly in predicting averages, that is, the average set of price changes one would expect given a certain set of conditions. Usually, an average set of changes will be different from the actual set of changes. That is why we built error terms into each of the equations. To make the simulated values as much like the original values as possible (except for the factors we changed), we added the estimated errors back to each of the equations. That way, the only difference between the actual and simulated prices would be the different levels of meat production and consumption.

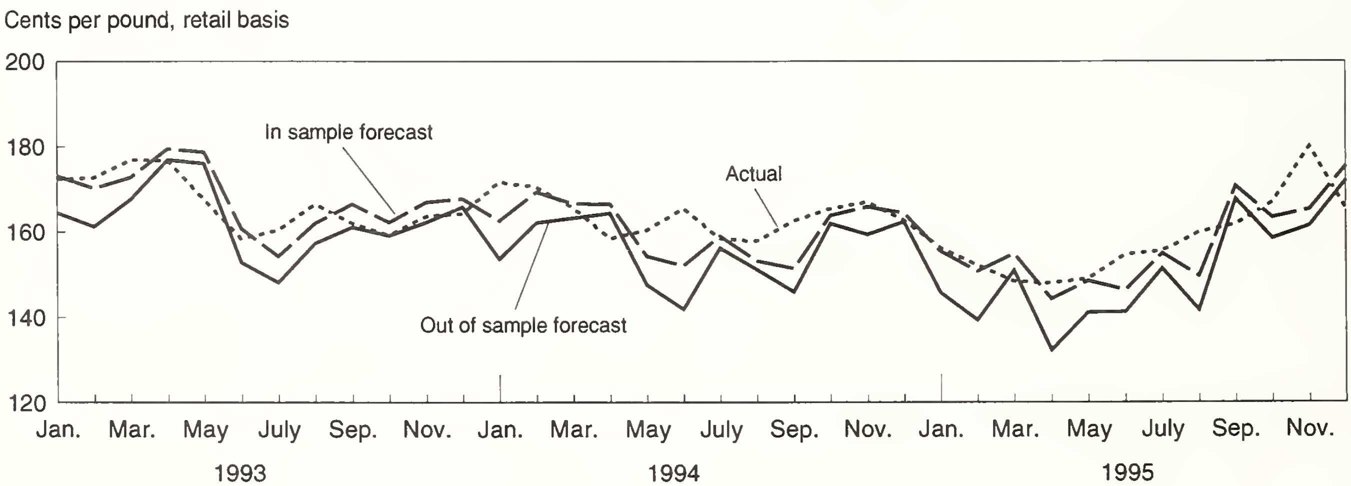
To no one's surprise, we found beef quantities were much more important in determining beef prices than the quantities of the other meats. Pork, chicken, and turkey quantities had only minor effects on December 1996 beef prices. Had beef production and consumption been steady since 1991, beef prices at all levels would have been noticeably higher, 15 to 20 cents per retail weight equivalent. Price spreads were much less affected by the changes in beef, pork, or poultry quantities. The largest part of the difference there occurred in the wholesale-retail spread, which was caused by the slow adjustment of the retail price.

Figure 8
Net farm values for beef, January 1993-December 1995



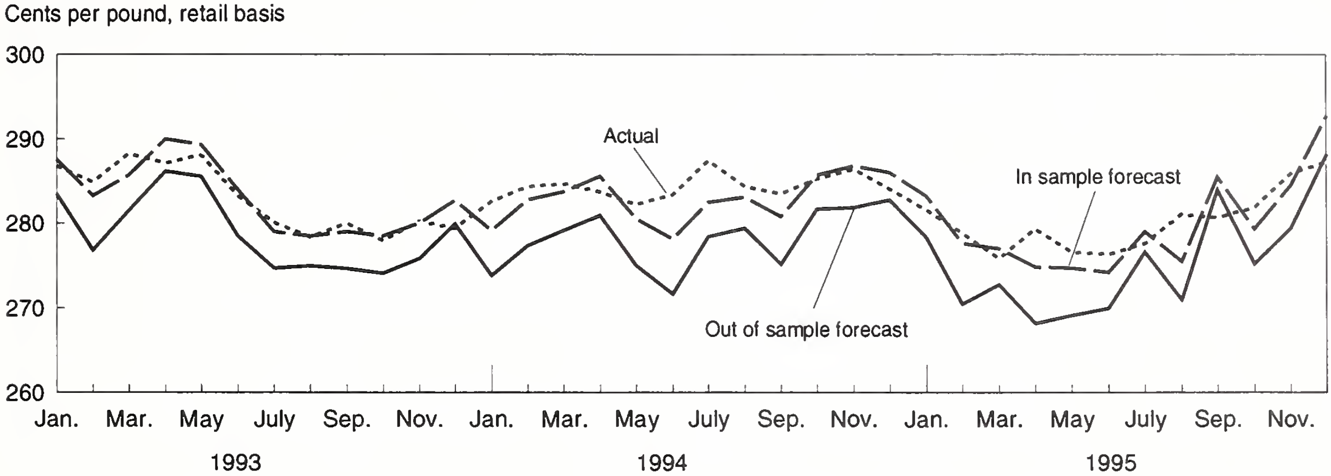
Source: USDA, ERS.

Figure 9
Wholesale values for beef, January 1993-December 1995



Source: USDA, ERS.

Figure 10
Retail values for beef, January 1993-December 1995



Source: USDA, ERS.

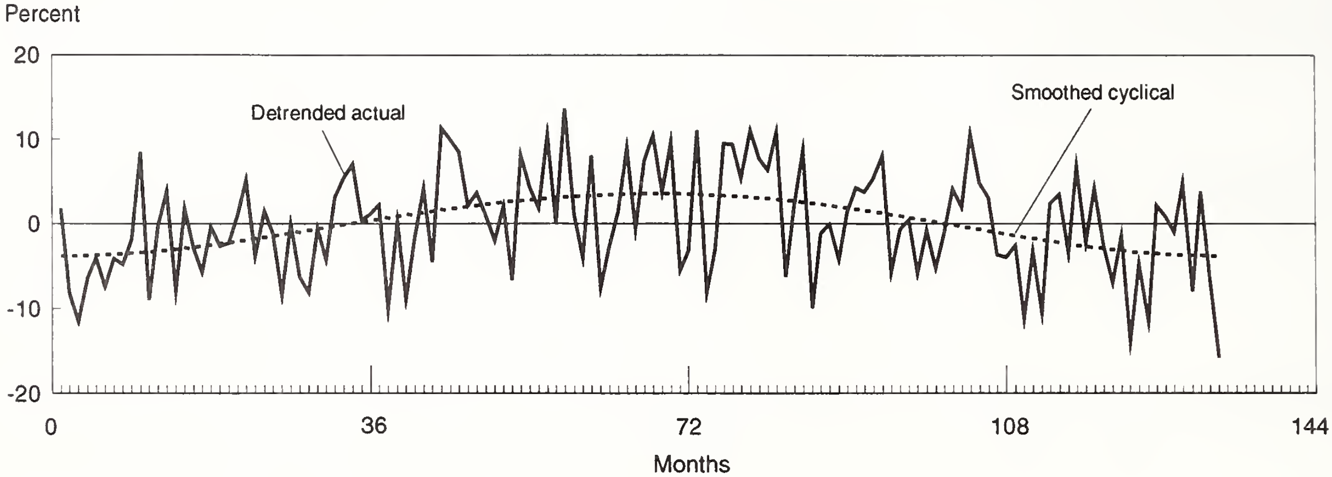
Cattle Cycle Effects

We used model simulations to see how the cattle cycle affected price spreads, in part, to see if there were price spread behaviors that depended on where in the cattle cycle they were. Econometricians often talk about dividing data series into trend, cyclical, seasonal, and transient components. We took the actual patterns of beef production and consumption from the 1980-90 cattle cycle and extracted the trend and cyclical parts (figs. 11 and 12). Since the cattle cycle implies relatively smooth changes in quantities from one month to the next, most of the month-to-month changes in beef quantities are due to the seasonal and transient parts, leaving a smooth pattern of prices (figs. 13 and 14). Further, the slow nature of cyclical quantity changes does not put much stress on price adjustment. As a result, we found almost no cyclical pattern in the price spreads themselves.

We simulated the effects of the cattle cycle by running only the cyclical parts of beef production and consumption through the model, with every other variable fixed. (We also eliminated the seasonal factors from the model.) We ran our simulation as a closed loop, that is, as if the cycle ran continuously forever. Our resulting prices represent a purely cyclical set. Figures 13 and 14 show prices and price spreads over the cattle cycle. Prices (fig. 13) show a definite cyclical pattern, varying almost 10 percent at the farm level over the cycle. Wholesale prices vary similarly, but not quite as extremely over the cattle cycle. Retail prices vary the least over the cattle cycle, varying only about 4 percent over the cycle.

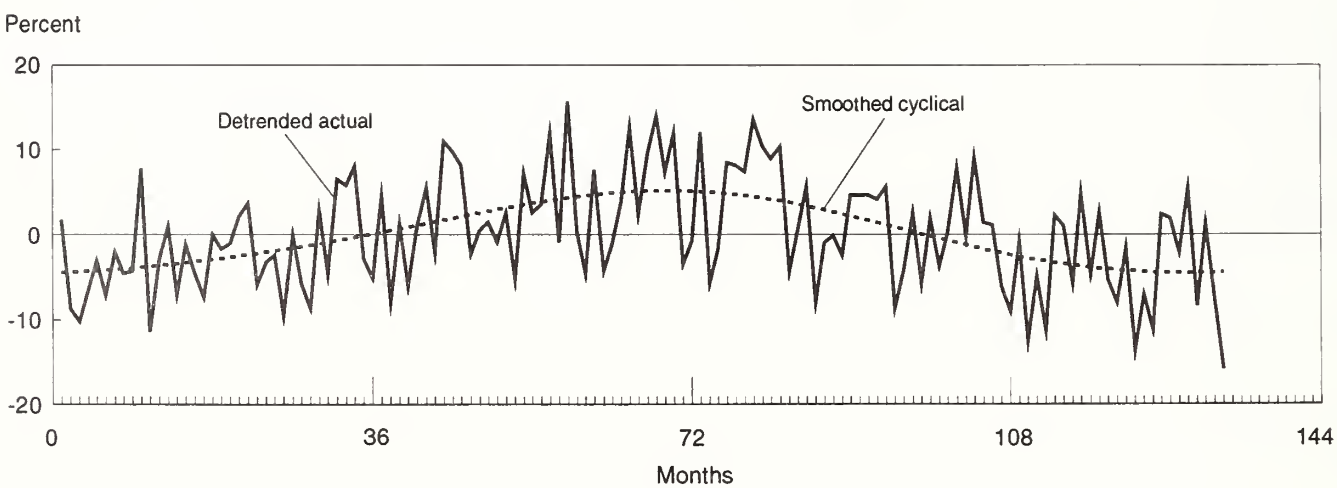
Price spreads also vary over the cattle cycle (fig. 14), but not much (less than 2 percent from peak to trough, and the three spreads are virtually identical). This is not to say that changes in cattle numbers are irrelevant to price spreads. The purely cyclical component of quantity changes is just not extreme enough to cause the wide changes in price spreads actually observed. Other variables, the higher frequency seasonal and transient changes (not shown in figs. 13 and 14), have greater effects on price spreads than do the cyclical components of prices and price spreads.

Figure 11
Beef production over the cattle cycle



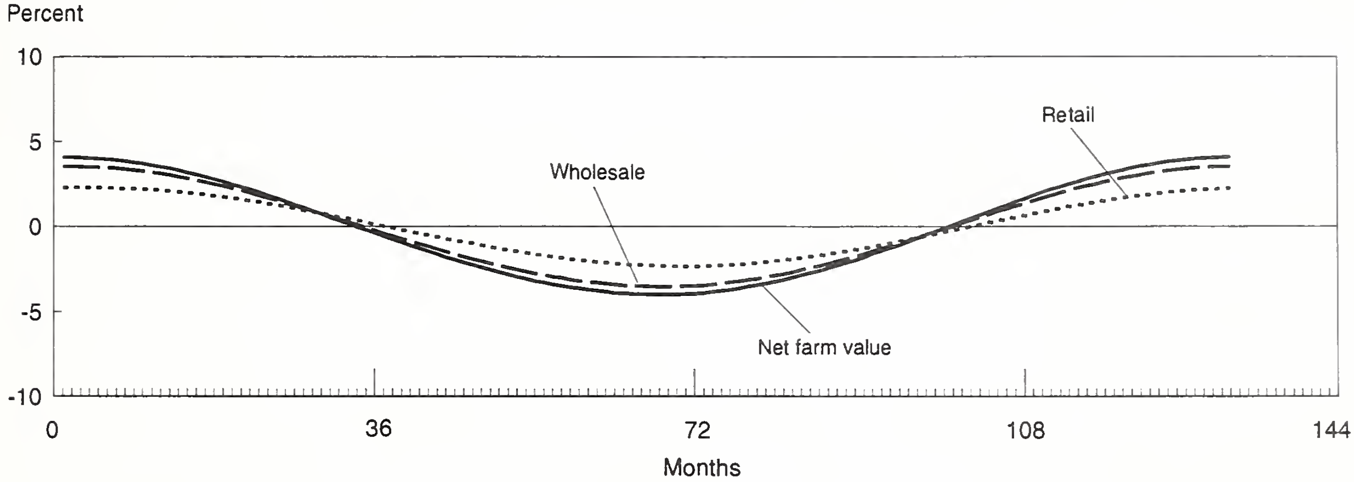
Note: The months start from the beginning of the cycle.
Source: USDA, ERS.

Figure 12
Per capita beef disappearance over the cattle cycle



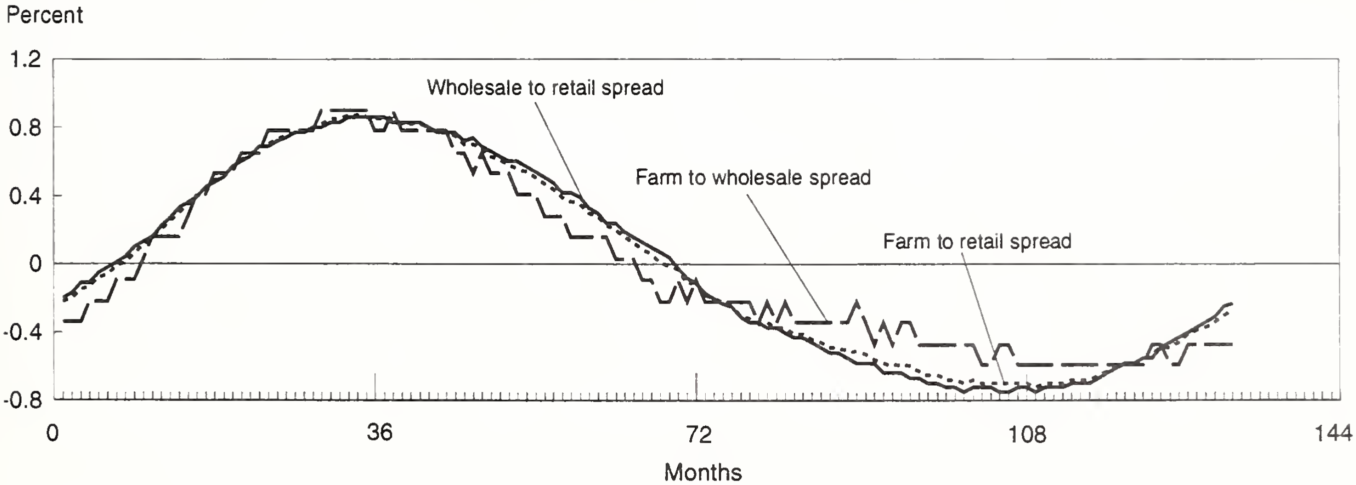
Note: The months start from the beginning of the cycle.
Source: USDA, ERS.

Figure 13
Deviation from average price over the cattle cycle



Note: The months start from the beginning of the cycle.
Source: USDA, ERS.

Figure 14
Deviation from average over the cattle cycle



Note: The months start from the beginning of the cycle.
Source: USDA, ERS.

Concentration Measures for the Beef Packing Industry

Azzam and Anderson reviewed the literature on structure, conduct, and performance issues related to the meatpacking industry (USDA, GIPSA,1996). They reviewed studies under two classifications: Structure, Conduct, and Performance (SCP) and New Empirical Industrial Organization (NEIO). Results were not consistent across studies for either classification.

SCP Studies

Azzam and Anderson reported that several studies of beef and pork packing concluded that market power, the ability to affect prices because of quantities transacted or market share affected by one or a few firms, can arise from concentration. However, the studies they reviewed, which differed widely in time period and analytical method, arrived at conflicting results. Some studies were faulted in that their observed correlations could be due to shifts in supply or demand not properly specified. Specifically, Azzam and Anderson alleged that links between supply elasticity and prices were not addressed in the regional price-concentration studies they reviewed. They also pointed out that economies of size rather than noncompetitive behavior, may be the cause of firm growth and increases in concentration.

NEIO Studies

Azzam and Anderson likewise reported a lack of consistent results across NEIO studies they reviewed. A pattern of results suggested exercise of market power in live cattle markets, but price effects seemed small and perhaps more than offset by cost reductions associated with consolidation. Market power did not increase with concentration as theory would suggest, and evidence indicated that packers were unable to sustain cooperation in restraining prices paid for cattle. They also concluded that empirical implementation has not equaled theoretical rigor due to lack of appropriate data and model complexity.

GIPSA Conclusions

GIPSA reported its conclusions from the Azzam and Anderson study as follows:

> The researchers' description of historical industry evolution suggests that changes in the meatpacking industry have resulted from technological change and dynamic rivalry between firms. The basic question addressed by this project was whether the evidence from Structure-Conduct-Performance and New Empirical Industrial Organization studies is persuasive enough to warrant the conclusion that competition in the meatpacking industry is deficient. Taken as a whole, the literature review led to the conclusion that the answer is no.
>
> Many SCP studies indicated the existence and exercise of market power. However, the failure to use appropriate theoretical models of conduct in these studies makes industry generalizations questionable.
>
> The NEIO studies show a persistent gap between the actual price of livestock and the competitively determined price predicted by theory. However, the studies have not incorporated sufficient detail to prove noncompetitive behavior.

Empirical Measures of Packer Concentration

As discussed above, the CR-4 (four-firm concentration ratio) for steer and heifer slaughter as reported by GIPSA rose to 50 percent in 1985, 72 percent in 1990, and 80 percent in 1996 (preliminary GIPSA, table 3). The CR-4 for boxed fed beef production for the same years was 62 percent, 79 percent, and 84 percent (1994). Tables 3 to 6 summarize these and additional comparisons.

The Herfindahl-Hirshman Index

Another, generally preferred, measure of concentration is the Herfindahl-Hirshman Index (HHI), also reported by GIPSA. The HHI has the advantage of taking into account the number of firms and relative distributional shares of the market held by all firms, not just the largest few. The HHI is calculated by summing each firm's squared percentage of the market. If 100 firms each have a 1-percent share, the HHI will equal 100. If 1 firm has 100 percent of the market, the HHI equals 10,000.

Table 3--Slaughter concentration for four largest firms, 1980-96

	Four-firm concentration				Herfindahl-Hirshman Index			
Year	Steer & heifer	Cow & bull	Cattle	Boxed fed beef	Steer & heifer	Cow & bull	Cattle	Boxed fed beef
	Percent				*Herfindahl-Hirshman Index*			
Concentration based on procurement data reported to GIPSA:								
1980	35.7	9.7	28.4	52.9	561	89	361	1,220
1981	39.6	9.6	31.4	57.1	643	96	410	1,359
1982	41.4	9.1	32.0	59.1	683	83	417	1,323
1983	46.6	10.3	36.0	60.2	862	96	522	1,382
1984	49.5	11.0	37.2	61.7	944	98	543	1,439
1985	50.2	17.2	39.0	61.5	999	160	617	1,527
1986	55.1	18.4	42.3	67.4	1,088	173	657	1,691
1987	67.1	20.0	54.2	79.5	1,435	206	946	1,981
1988	69.7	18.4	56.6	79.3	1,589	198	1,055	2,030
1989	70.4	17.5	57.0	79.2	1,602	188	1,055	1,979
1990	71.6	20.4	58.6	79.3	1,661	223	1,118	1,988
1991	73.5	21.1	60.6	78.7	1,766	236	1,204	1,958
1992	77.8	22.0	63.5	81.4	2,005	243	1,336	2,163
1993	79.8	24.0	66.0	82.7	2,052	276	1,393	2,236
1994	80.9	26.3	67.8	85.7	2,096	320	1,460	2,340
1995	79.3	23.4	67.3	84.3	1,982	293	1,437	2,208
Concentration based on federally inspected slaughter data:								
1991	74.5	21.1	NA		NA	NA	NA	NA
1992	79.0	23.6	NA		NA	NA	NA	NA
1993	81.9	25.1	NA		NA	NA	NA	NA
1994	81.8	24.9	NA		NA	NA	NA	NA
1995	81.1	26.1	NA		NA	NA	NA	NA
1996	80.0	27.2	NA		NA	NA	NA	NA

NA = Not applicable.

Source: U.S. Dept. of Agriculture, Packers and Stockyards Statistical Report: 1995 Reporting Year, GIPSA 97-1, September 1997, Tables 27, 28, and 29.

Table 4—Livestock slaughter plants, by type of inspection, 1972-95[1]

Year	Plants reporting to GIPSA[2] Under Federal inspection	Plants reporting to GIPSA[2] Non-Federal inspection	Total	Under Federal inspection January 1	Non-Federal inspection January 1	Total Federal and non-Federal inspection
			Number of plants			
1972	735	405	1,140	984	5,172	6,156
1973	753	357	1,110	1,364	4,627	5,991
1974	741	322	1,063	1,437	4,440	5,887
1975	767	274	1,041	1,485	4,602	6,087
1976	761	288	1,049	1,741	4,514	6,255
1977	776	224	1,000	1,682	4,454	6,141
1978	785	213	998	1,701	4,434	6,135
1979	760	207	967	1,687	4,445	6,127
1980	762	209	971	1,627	4,399	6,026
1981	714	187	901	1,542	4,330	5,872
1982	728	156	884	1,688	4,048	5,736
1983	749	144	893	1,652	4,037	5,689
1984	730	137	867	1,666	3,892	5,558
1985	687	117	804	1,608	3,835	5,443
1986	640	99	752	1,544	3,701	5,245
1987	620	102	722	1,483	3,523	5,006
1988	606	99	705	1,387	3,453	4,840
1989	552	87	639	1,364	3,325	4,689
1990	534	89	623	1,268	3,281	4,549
1991	497	90	587	1,186	3,140	4,326
1992	490	79	569	1,125	2,896	4,021
1993	457	77	534	1,090	2,797	3,887
1994	434	66	500	1,030	2,733	3,763
1995	429	58	487	968	2,627	3,595

[1]Slaughter plants came under Federal inspection in the following 20 States after 1972: AR-6/81; CA-4/76; CO-7/75; CT-10/75; ID-7/81; KY-1/72; ME-5/80; MA-1/76; MD-3/91; MI-10/81; MO-8/82; NV-7/73; NH-8/78; NJ-7/75; NY-7/75; OR-7/72; PA-7/72; RI-10/81; TN-10/75 and WA-6/73. Many non-federally inspected plants can only custom slaughter for others.

[2]Plants reporting to GIPSA include federally and non-federally inspected establishments. Firms purchasing less than 2,000 head of all livestock, or less than 1,000 head of cattle prior to 1977, or less than $500,000 of all livestock beginning in 1977 were not required to report to GIPSA.

Source: U.S. Dept. of Agriculture, Packers and Stockyards Statistical Report: 1995 Reporting Year, GIPSA 97-1, September 1997, Table 18.

Table 5--Steers and heifers: Slaughter by plant size, packers reporting to GIPSA, by plant size (head), 1972-95

Year	Less than 1,000		1,000-9,000		10,000-49,999		50,000-99,999		100,000-249,999		250,000 or larger[1]		500,000 or larger[2]		1 million or larger	
	Plants	Head	Plants	Head	Plants	Head	Plants	Head	Plants	Head	Plants	Head	Plants	Head	Plants	Head
	No.	*1,000*	*No.*	*1,000*	*No.*	*1,000*	*No.*	*1,000*	*No.*	*1,000*	*No.*	*1,000*	*No.*	*1,000*	*No.*	*1,000*
1972	173	75	319	1,209	174	4,132	73	5,257	48	7,682	20	7,778				
1973	192	84	302	1,127	166	4,001	75	5,464	37	5,876	23	8,657				
1974	178	80	281	1,037	156	3,893	68	4,781	47	7,153	22	8,457				
1975	159	77	288	1,127	150	3,685	67	4,617	49	7,530	22	8,536				
1976	147	71	300	1,134	144	3,301	71	4,857	52	8,187	17	6,074	5	3,334		
1977	130	61	270	1,030	142	3,225	74	5,303	49	7,646	20	7,085	7	4,700		
1978	155	73	256	910	141	3,256	56	4,125	49	8,083	17	6,079	9	5,851		
1979	182	78	238	843	109	2,795	44	3,117	47	7,420	15	5,103	9	6,256		
1980	201	87	212	715	107	2,644	43	3,063	37	5,813	18	6,280	8	5,877		
1981	177	79	185	660	80	1,984	33	2,332	32	4,998	22	7,920	10	7,521		
1982	181	75	172	590	69	1,771	31	2,293	28	4,497	20	7,119	12	9,131		
1983	183	73	172	540	68	1,625	29	2,093	25	3,836	19	6,746	14	11,133		
1984	178	71	155	511	64	1,559	24	1,686	27	4,515	16	5,665	15	12,232		
1985	157	63	146	445	56	1,439	19	1,366	27	4,276	14	4,999	17	14,434		
1986	137	54	133	460	45	1,109	19	1,328	20	3,204	12	4,295	13	9,955	5	6,232
1987	152	53	128	435	34	776	20	1,383	23	4,056	10	3,444	12	8,561	7	8,438
1988	151	50	121	388	37	819	16	1,167	17	2,759	13	4,338	12	8,661	7	8,993
1989	138	49	92	304	32	803	12	891	13	2,141	13	4,426	12	8,677	7	8,595
1990	142	49	86	248	29	690	7	477	13	2,058	15	5,223	10	7,245	8	9,770
1991	130	48	81	235	26	577	6	410	15	2,614	14	5,563	10	8,470	6	7,462
1992	127	51	78	240	17	420	4	281	13	2,006	9	3,133	13	10,499	7	8,661
1993	131	44	66	175	21	465	3	216	12	1,926	8	3,164	9	6,810	11	12,751
1994	98	31	72	207	21	479	4	318	7	1,100	6	2,351	11	8,079	11	13,562
1995	96	36	58	170	19	421	5	369	9	1,533	7	2,692	10	7,194	12	14,934

[1]Size limits are 250,000-499,999 beginning in 1976.
[2]Size limits are 500,000-999,999 beginning in 1986.

Source: U.S. Dept. of Agriculture, Packers and Stockyards Statistical Report: 1995 Reporting Year, GIPSA 97-1, September 1997, Table 20.

Table 6--Cows and bulls: Slaughter by plant size, packers reporting to GIPSA, by plant size (head), 1972-95

Year	Less than 1,000		1,000-9,000		10,000-24,999		25,000-49,999		50,000-99,999		100,000 or larger[1]		150,000 or larger	
	Plants	Head	Plants	Head	Plants	Head	Plants	Head	Plants	Head	Plants	Head	Plants	Head
	No.	*1,000*	*No.*	*1,000*	*No.*	*1,000*	*No.*	*1,000*	*No.*	*1,000*	*No.*	*1,000*	*No.*	*1,000*
1972	279	110	359	1,272	82	1,340	47	1,604	18	1,235	6	801		
1973	268	107	333	1,138	74	1,208	44	1,563	23	1,702	3	481		
1974	248	94	316	1,140	68	1,133	39	1,362	31	2,240	6	927		
1975	206	83	302	1,107	83	1,298	57	2,046	36	2,440	22	2,959		
1976	202	85	298	1,149	74	1,183	74	2,558	41	2,740	17	2,104	5	917
1977	193	79	299	1,153	76	1,206	61	2,118	35	2,433	13	1,609	5	920
1978	206	82	295	1,172	65	1,066	57	1,942	38	2,648	9	1,074	5	917
1979	243	98	262	957	52	855	39	1,277	30	1,945	7	810	3	489
1980	250	93	240	832	56	926	46	1,609	21	1,539	4	482	5	807
1981	213	86	206	728	55	887	40	1,397	24	1,664	6	669	7	1,153
1982	207	86	195	741	44	744	45	1,594	25	1,700	9	1,063	6	1,012
1983	197	77	199	775	48	809	51	1,814	21	1,490	8	943	8	1,541
1984	192	73	171	648	48	800	48	1,745	27	1,874	12	1,400	8	1,661
1985	188	71	145	572	48	764	40	1,411	17	1,333	12	1,427	8	1,666
1986	149	55	133	478	43	680	41	1,430	16	1,124	20	2,320	8	1,770
1987	154	51	121	441	48	775	32	1,104	24	1,778	13	1,572	7	1,470
1988	146	48	127	483	36	588	29	934	21	1,541	13	1,618	7	1,402
1989	136	46	110	408	33	579	25	857	17	1,300	8	964	11	2,159
1990	140	45	99	330	28	500	17	597	19	1,311	11	1,349	10	2,001
1991	127	42	89	311	24	400	21	766	18	1,344	10	1,274	10	1,933
1992	120	42	77	300	25	435	15	526	15	1,104	10	1,263	12	2,238
1993	114	42	66	244	20	350	12	456	14	1,031	10	1,214	14	2,777
1994	104	38	53	212	19	313	13	474	18	1,372	10	1,282	12	2,596
1995	93	27	58	224	18	314	12	445	12	885	9	1,083	17	3,510

[1]Size limits are 100,000-149,999 beginning in 1976.

Source: U.S. Dept. of Agriculture, Packers and Stockyards Statistical Report: 1995 Reporting Year, GIPSA 97-1, September 1997, Table 21.

The U.S. Department of Justice and Federal Trade Commission Horizontal Merger Guidelines (April 1992) provide insight into the HHI levels considered important in determining whether mergers within a relevant market are likely to be challenged by the Justice Department:

> Post-Merger HHI below 1,000. The Agency regards markets in this region to be unconcentrated. Mergers resulting in unconcentrated markets are unlikely to have adverse competitive effects and ordinarily require no further analysis.
>
> Post-Merger HHI between 1,000 and 1,800. The Agency regards markets in this region to be moderately concentrated. Mergers producing an increase in the HHI of less than 100 points in moderately concentrated markets post-merger are unlikely to have adverse competitive consequences and ordinarily require no further analysis. Mergers producing an increase in the HHI of more than 100 points in moderately concentrated markets post-merger potentially raise significant competitive concerns depending on the factors set forth in Sections 2-5 of the Guidelines.
>
> Post-Merger HHI above 1,800. The Agency regards markets in this region to be highly concentrated. Mergers producing an increase in the HHI of less than 50 points, even in highly concentrated markets post-merger, are unlikely to have adverse competitive consequences and ordinarily require no further analysis. Mergers producing an increase in the HHI of more than 50 points in highly concentrated markets post-merger potentially raise significant competitive concerns, depending on the factors set forth in Sections 2-5 of the Guidelines. Where the post-merger HHI exceeds 1,800, it will be presumed that mergers producing an increase in the HHI of more than 100 points are likely to create or enhance market power or facilitate its exercise. The presumption may be overcome by a showing that factors set forth in Sections 2-5 of the Guidelines make it unlikely that the merger will create or enhance market power or facilitate its exercise, in light of market concentration and market shares (Section 1.5).

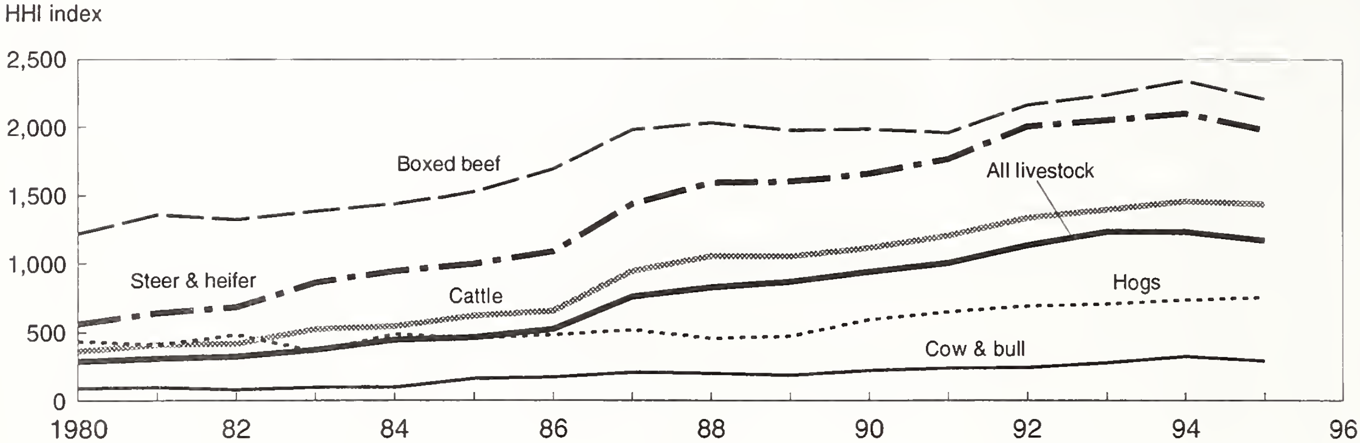
The HHI for U.S. steer and heifer slaughter was 999 in 1985, 1,661 in 1990, and 1,982 in 1995, above the threshold 1,800 level (fig.15). For all cattle slaughter combined, the HHI's are much lower, reaching only 1,437 in 1995. For U.S. boxed fed beef, the HHI's are 1,527; 1,988; and 2,208, respectively. If the relevant market were defined as steer and heifer slaughter or boxed fed beef production by the U.S. Department of Justice, it would seem that future major mergers would be candidates for challenge. On the other hand, if the relevant market were defined as cattle slaughter or all livestock purchases, merger challenges would be less likely (tables 3 to 6).

HHI and Our Asymmetric Model

It is clear that steer and heifer slaughter concentration and fed boxed beef concentration is high by several standards. It is far less clear what caused industry consolidation or what effects stem from high concentration, and whether any effects constitute market distortions adverse to producers.

We tested for the effects of concentration by including the HHI in our asymmetric model. We had HHI measures for only a limited part of the sample. The HHI was statistically significant in the sub-sample, but its effects were opposite from what one would expect. If packers were using market power to gain an unfair advantage over producers, one would expect market power to lead to lower farm prices and/or higher farm-to-wholesale spreads. However, in our results, increasing HHI was associated with higher farm prices and lower farm-to-wholesale spreads. This type of unexpected result is common in other studies of market concentration's effects on livestock markets.

Figure 15
Herfindahl-Hirshman Index for the meatpacking industry, by category, 1980-96



Source: USDA, ERS, from data provided by USDA's, Grain Inspection, Packers and Stockyards Administration.

While the estimated HHI effect is counter-intuitive, it is also small. As we move from the smallest HHI to the largest HHI, the farm-wholesale spread drops by less than 1 cent. This drop in the farm-wholesale spread translates into a 2-cents-per-pound increase in the live price of choice cattle; retail and wholesale prices are basically unaffected by the HHI. The large amount of data in the asymmetric model make it able to measure relatively small effects with great accuracy. The small measured effect of the HHI is very statistically significant even though it has little practical effect.

There are a number of reasons why the HHI could give this counter-intuitive result. Market concentration may be driven in part by economies of size. Farm-to-wholesale spreads could be dropping as concentration rises because some part of the cost-savings from larger slaughter operations are shared with producers. Also, the HHI may not be the most appropriate measure of market power. There is a difference between the ability to exercise market power, for example, concentration, and the actual exercise of market power (Jones, Purcell, Driscoll, and Peterson, 1996). The HHI is meant to measure the ability to exercise market power. It is generally assumed in the literature that the exercise of market power by an industrial organization is reliably related to the ability to exercise it. The reality may be more complex.

Conclusions

The cattle cycle of the 1990's that began in 1991 reached a peak in cattle numbers of 103,819 thousand head in 1996. A drought in early 1996 resulted in a more severe cattle sell-off than would probably have occurred otherwise, possibly shortening the consolidation period that often follows an expansion phase of the cattle cycle or perhaps shortening the entire cycle. The increased sell-off of cattle during 1996 was accompanied by the second lowest real net receipts above cash costs since 1913. Total beef production has been above 25 billion pounds since 1994 and was 25.7 billion pounds in 1998, the same as the peak in 1976.

The percentage increase in cattle numbers from the beginning of the 1991-to-present cycle was the second lowest since the cattle cycle that began in 1913. The smallest percentage increase in cattle numbers and the shortest expansion phase for a cattle cycle was the previous cycle of the 1980's. Interestingly, total beef production has trended upward since at least the late 1940's, and the last three cyclical peaks in total beef production have been within a billion pounds of each other. The large bulge during the late 1970's is the only significant change in this trend since World War II.

However, nothing in the data suggests that the adverse profit situation of 1996 that prompted the latest round of packer concentration studies was unexpectedly worse or out of character for where the cattle industry was in 1996 in terms of the cattle cycle of the 1990's. The research reported here did not find cattle inventory numbers or net returns to cow/calf producers above cash costs to have fluctuated during the 1990's beyond what would have been expected at least 95 percent of the time. Further, our estimates imply that, while there was a shift in pricing system behavior during 1992 to 1996, the shift raised prices for live cattle, wholesale, and retail beef prices higher than they would have been, given their earlier patterns of reaction to supply and demand shocks. The farm-wholesale price spread has been unaffected by the shift, and the wholesale-retail spread has declined. The out-of-sample forecasts, based on coefficients using 1979-91 data, are generally lower than in-sample forecasts, further evidence that the recent shifts in the system actually led to higher prices.

One of the notable features of beef prices is that farm and wholesale prices are more volatile than retail prices. Also, it often appears that retail prices are following farm and wholesale prices. That is, retail prices tend to go up a month or more after the others go up and drop a month or more after the others drop.

Grain Inspection Packers and Stockyards Administration (GIPSA) summarized its work as follows (USDA, 1996):

> The findings of the extensive literature reviewed were inconclusive about the effects of concentration, primarily because of limitations in the methods or data, or both, in the literature reviewed. While the body of evidence from the literature was insufficient to support a finding of noncompetitive behavior, it also cannot conclude that the industry is competitive (p. 55).

Azzam and Anderson's portrayal of the difficulty in assessing the competitiveness from available data held true for another of the studies contracted by GIPSA titled Effects of Concentration on Prices Paid For Cattle. The GIPSA summary states:

> The analysis did not support any conclusions about the exercise of market power by beef packers. It appears that improved models are needed to more fully incorporate relevant determinants of firms' behavior (p. 36).

The effects of market concentration are widely debated and were included in the analyses here, with interesting results. Slaughter concentration effects were represented in our model specifications by the HHI. Coefficient estimates for the HHI indicate that: (1) increasing HHI was significantly associated with higher prices and narrower

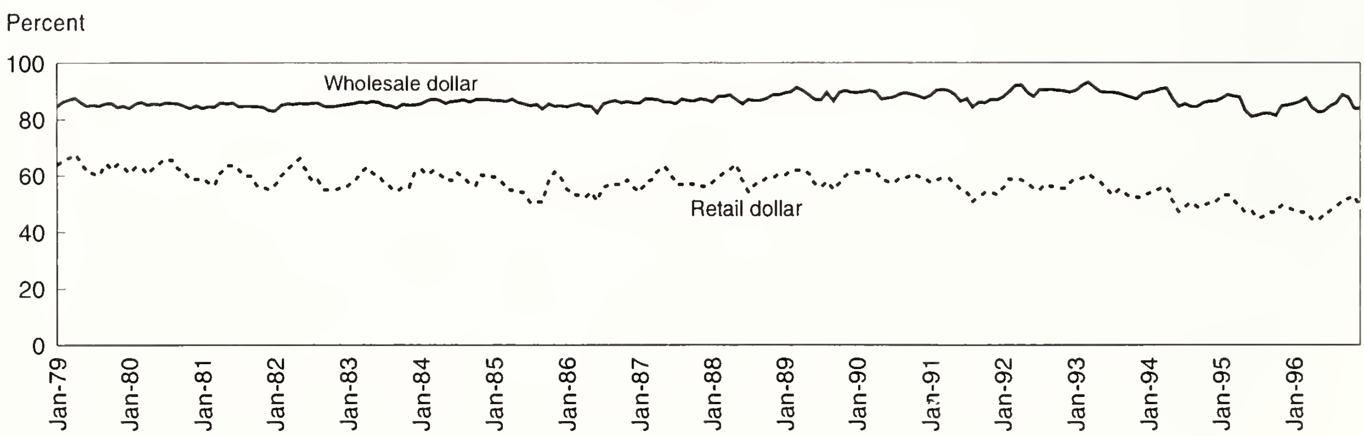
farm-to-wholesale spreads, (2) increasing slaughter concentration is associated with higher farm prices, and (3) other factors not identified in our analysis were associated with size and concentration have been more important than monopsonistic price effects. Despite these results that suggest that packers do not appear to be exercising market power, it is also clear that with concentration measures of 80 percent or higher, the potential for exercising market power in the industry does exist. Continued monitoring of market concentration and additional research into better measures of the existence and use of market power would be helpful.

Beef producers have expressed concern over the low prices and low producers' share of the retail dollar. Most of their attention has been directed at beefpackers, even though the largest part of the spread between farm and retail occurs between the packer and the retailer.

Figure 16 shows that the producers' share of the wholesale dollar has been more stable than the producers' share of the retail dollar, which has trended roughly downward since the end of the 1970's. While it is true that the producers' share of the wholesale dollar hit its lowest value in the 1979-96 period in June 1995, it also hit its highest value in March 1993. The minimum value in June 1995 is also similar to the lower values in the whole time period.

A notable feature of the producers' share of wholesale dollars in the 1990's has been an apparent increase in volatility that has led to occasions with unusually high shares. The largest producers' shares occur in the 1990's. The picture is much different for the producers' share of the retail dollar. Most of the largest shares occur early in the time period. The lowest 30 shares in this sample occur in the 1990's.

Figure 16
Beef producers' shares of wholesale and retail dollars, January 1979-December 1996



Source: USDA, ERS.

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Appendix table--Data series for cattle cycle analysis

Variable	Length of time series	Period of estimated data	Data source
All cattle and calves	1867-1997	NC	Agricultural Statistics
Average live weight	1935-1996	NC	Agricultural Statistics
Average price/cwt	1935-1996	NC	Agricultural Statistics
Dollars per head	1867-1996	NC	Agricultural Statistics
Dairy cows	1930-1997	NC	Agricultural Statistics
All hogs and pigs	1867-1997	NC	Agricultural Statistics
Consumer price index	1913-1995	NC	Agricultural Statistics
Costs of and gross receipts to production	1972-1995	1913-1972, 1996	*Cost of Production* summaries
Farm output productivity indexes	1910-1988	NC	Agricultural Statistics
Farm input productivity indexes	1910-1988	NC	Agricultural Statistics
Per-capita beef and veal consumption	1909-1997	NC	Agricultural Statistics
Per-capita pork (and lamb) consumption	1909-1997	NC	Agricultural Statistics
Per-capita red meat consumption	1909-1997	NC	Agricultural Statistics
Heifers 1 to 2 years old	1931-1969	1970-1997	Agricultural Statistics

NC = No data were constructed.

Appendix B--Our Asymmetric Model of Price Movements

Since we have three things to explain (the farm, wholesale, and retail prices of beef), our model has to have three equations. One equation focuses on the general level of prices and the other two look at the spread between farm and wholesale prices and between wholesale and retail prices. Our three equations allow adjustment in the general price level, adjustment to the farm-wholesale spread, and adjustment to the wholesale-retail spread. All the adjustment equations compare where something is to where it should be and require prices to adjust to get them closer to where they should be. That is, our adjustment equations are based on the idea that there is a target value for the price level or some spread. The target level is a longrun value, that is, if current conditions were fixed forever, prices and spreads would eventually settle down to their targets. In our adjustment models, it is possible for prices or spreads to go immediately to their targets, or to go partially toward their targets, or even to over-shoot their targets. If the general price level is too low, having one or all of the prices increase could get the general price level to where it should be. If the farm-wholesale spread is too low, increasing the wholesale price or decreasing the farm price could make the spread closer to what it should be. Also, if the wholesale-retail spread needs to increase, either the retail price goes up or the wholesale price goes down.

Solving endogenous switching models such as our asymmetric model can be more complicated than solving symmetric models. In fact, there are special coherency conditions on the model's parameters. If these are not met, the model's equations may not have a solution in some cases or might have more than one solution in other cases. Gourieroux, Laffont, and Monfort (1980) have a complete explanation of why coherency is necessary and what the coherency conditions are. In our case, it turns out that we can impose coherency by forcing the parameters to take sensible values. For example, if the wholesale price follows the farm price, a set of sensible values would make the wholesale price go up (or at least not down) when the farm price goes up, and vice versa.

Price Level Equation

Our first equation is the price-level equation. We will explain our price-level equation by starting with a simple form, then adding complications until we reach the final functional form that we used.

One common hypothesis in this type of research is that prices are determined at the farm level and wholesale and retail prices follow the farm price. Suppose that this was the case. Suppose that f_t is the farm price in month t, (f_{t-1} is the previous month's farm price) and that F_t is the target farm price. To hit its target in month t, the farm price has to move from f_{t-1} to F_t. In partial adjustment models, the actual change in the price can be less than that needed to get the price to its target level. In our simple model, actual movement between months t and t-1, which is f_t-f_{t-1}, is given by the formula:

$$\alpha_{1,f}\,(f_t - f_{t-1}) = F_t - f_{t-1}. \tag{1}$$

Equation 1 is written in a slightly unusual way, but this specification simplifies the task of programing the estimation routine. The type of adjustment from equation 1 depends on the value of $\alpha_{1,f}$. If $\alpha_{1,f}$ is 1, there is complete adjustment. If the term is greater than one, a smaller change on the left-hand side balances a larger change on the right-hand side, resulting in partial adjustment. A value under 1 leads to overshooting. The sensible values for $\alpha_{1,f}$ are positive. A negative value means that prices adjust away from their equilibrium values.

To make equation 1 asymmetric, allow the value of $\alpha_{1,f}$ to vary depending on the sign of (f_t - f_{t-1}). This will give two values for the coefficient, $\alpha^{+}_{1,f}$ when the farm price increases and $\alpha^{-}_{1,f}$ when the farm price decreases. We now write equation 1 as:

$$\alpha^*_{1,f}(f_t - f_{t-1}) = F_t - f_{t-1} \tag{2}$$

where $\alpha^*_{1,f}$ is $\alpha^+_{1,f}$ or $\alpha^-_{1,f}$ depending on the direction that farm prices actually change.

When we set up our equations, we did not want to pre-specify that the farm price leads the other two prices. We did not, in fact, want to specify that any particular price leads the others. So we modified equation 2 to come up with our final form. Call the general target price level for month t, G_t, and assume that the general price level in month t-1 is some weighted average of the farm price, the wholesale price, w_{t-1}, and the retail price, r_{t-1}. To help ensure that the adjustment process is stable, we require that the weights on the lagged prices be positive. If prices are in general too low, we can get closer to the equilibrium price level by raising farm, wholesale, or retail prices. Our general price-level equation is written:

$$\alpha^*_{1,f}(f_t - f_{t-1}) + \alpha^*_{1,w}(w_t - w_{t-1}) + \alpha^*_{1,r}(r_t - r_{t-1}) = G_t - \beta_{1,f}f_{t-1} - \beta_{1,w}w_{t-1} - \beta_{1,r}r_{t-1},$$

where

$$\begin{aligned} &\alpha^*_{1,i} \geq 0,\ i = \{f,w,r\} \text{ and } * = \{+,-\} \\ &\alpha^*_{1,i} = \alpha^+_{1,i}, \text{ when } i_t - i_{t-1} > 0, \\ &\quad = \alpha^-_{1,i}, \text{ when } i_t - i_{t-1} < 0, \\ &\Sigma\beta_{1,i} = 1, \text{ and} \\ &\beta_{1,i} \geq 0,\ i = \{f,w,r\}. \end{aligned} \tag{3}$$

We will leave the specification of G_t until later.

We would like to point out that equation 3 does not actually require that all prices increase when the general target price, G_t, is greater than the last month's price. However, if any price decreases, some other price would have to pick up the slack by increasing enough to offset the decrease in the other price and balance the right-hand side of equation 3. However, equation 3 does imply that if the last month's price level is too low, at least one price has to increase this month.

Farm-to-Wholesale Price Spread Equation

The next equation in our system is the farm-to-wholesale spread equation. Call the target spread in month t, $S_{2,t}$. The spread in the previous month can be calculated as $(w_{t-1} - f_{t-1})$. If the current target spread is higher than last month's spread, we can move closer to equilibrium if the farm price goes down or if the wholesale price goes up. We can write the farm-wholesale spread equation as:

$$\alpha^*_{2,w}(w_t - w_{t-1}) - \alpha^*_{2,f}(f_t - f_{t-1}) = S_{2,t} - w_{t-1} + f_{t-1} \tag{4}$$

All the αs in equation 4 are required to be positive. (When we estimated the model, it was easier to specify that the $\alpha^*_{2,f}$ be added on the left-hand side, but that their sign be negative.) If last month's spread was lower than this month's target, prices can adjust to get the spread closer to its target by dropping the farm price or raising the wholesale price.

As in equation 3, equation 4 does not require that farm price go down or that the wholesale price go up when the target spread is larger than the old spread. One price can move in the "wrong" direction, however. If one goes in the "wrong" direction, the other has to move even more in the "right" direction to correct. Equation 4 does require that either the wholesale price rise or the farm price fall when the target spread is larger than last month's spread. Again, we specified equation 4 so that it could handle a wide variety of cases. Equation 4 is valid if the farm price leads the wholesale price, if the farm price follows the wholesale price, and cases when their interactions are more complex.

Wholesale-Retail Price Spread Equation

The last equation is the wholesale-retail spread. This equation is similar to equation 4: the wholesale price replaces the farm price and the retail price the wholesale, and there is a different target spread, but otherwise the structure and interpretations are identical. We use the same type of sign constraints and our model is valid for all general types of wholesale-retail price interactions.

$$\alpha^*_{3,r}(r_t - r_{t-1}) - \alpha^*_{3,w}(w_t - w_{t-1}) = S_{3,t} - r_{t-1} + w_{t-1} \tag{5}$$

The target levels and spreads determine the longrun retail, wholesale, and farm prices, that is, if the target levels were fixed for a time, eventually all three prices would get to their respective target levels. We have not yet specified how these longrun targets are determined. As is the case for models of this type, these target levels are functions of other variables. As these variables change over time, the targets change over time as well. However, even though the targets change, we will refer to a variable's effect on the target level as its longrun effect. Because our model allows for partial adjustment, the shortrun effects of variables can vary from their longrun effects.

Targets

Our model allows changes in supply and demand conditions to affect price spreads in the short run but not in the long run. To account for this, the price-spread equations contain the change in the supply and demand variables, but not their lagged values. If the other variables were stabilized for a long period of time, that is, they did not change, their level would have no effect on the target price spread. Supply and demand variables affect the shortrun and longrun price level, so the price-level equation has both the changes and the lagged values. Also, no statistical model is perfect: minor variables could be missing, and even purely random effects could affect price levels and spreads. These random effects are modeled as error terms, which we designate as $e_{i,t}$. If we call the current value of the supply and demand variables, X_t, the change in these between month t-1 and t, dX_t, and the set of intercept, trend, and seasonal variables, I_t, then our equations for the longrun price level target and longrun spread targets can be written:

$$G_t = dX_t g_{1,dX} + X_{t-1} g_{1,X} + I_t g_{1,I} + e_{1,t}, \tag{6}$$

$$S_{2,t} = dX_t g_{2,dX} + I_t g_{2,I} + e_{2,t}, \text{ and} \tag{7}$$

$$S_{3,t} = dX_t g_{3,dX} + I_t g_{3,I} + e_{3,t}. \tag{8}$$

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